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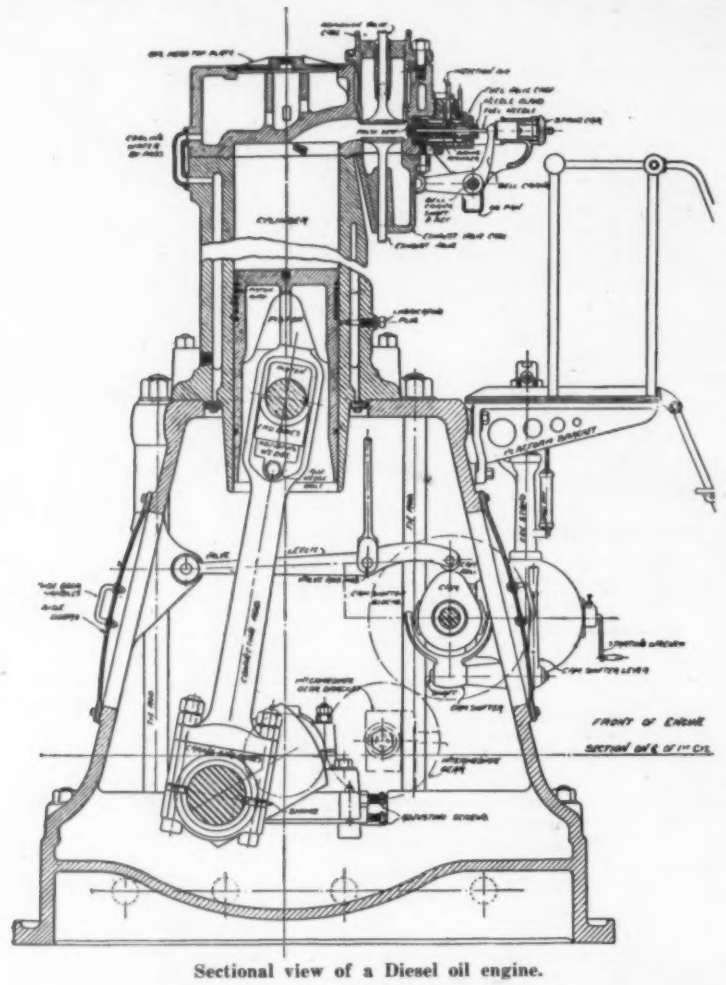
PHOTOGRAPH OF A FIGHT WITH A SHARK TAKEN UNDER WATER WITH THE WILLIAMSON APPARATUS.

The Diesel Engine*

Its Principles of Operation, Applications and Possibilities

THE development of the internal combustion engine has made tremendous strides in the last few years. This is especially true of one type in particular, the Diesel engine.

The unparalleled progress of this prime mover, due primarily to the expiration of the basic Diesel patents, has created a wave of enthusiasm the crest of which swept over this country only a short time ago. To the careful observer, however, signs of an ebbing of this wave



Sectional view of a Diesel oil engine.

are apparent, and more sober, more healthy views are rapidly gaining ground. The application of the engine to marine work, especially to vessels of certain classes, has been especially noticeable, and the marine interests of the country have been watching closely the work of the Diesel engineers. Other applications of the engine are common, and the Diesel engine of to-day is apt to be found in almost any line of work.

In spite of the fact that the name Diesel has spread over the world, but few engineers in fields other than combustion engineering have ever taken the time to thoroughly study the movement of the engine and to learn of its proved practical application and use to the engineering world.

The purpose of this article is, therefore, to present to the general engineer and the growing student an idea of what the Diesel engine is, and to show in what fields the greater possibilities of the engine lie.

This type of engine may be defined in a few words as follows:

An internal combustion engine which takes its fuel—crude, lowest grade of fuel oil, or the residues from oil refining—into the cylinders, raw, without any previous transforming, and there converts it into energy, exerting that energy directly on the crankshaft through pressure on the piston head, without any intermediaries, producing the simplest, most direct and economical operation.

PRINCIPLE OF OPERATION.

The cycle of operation of the Diesel engine operating on the "four-stroke-cycle" comprising the Diesel ignition-compression is as follows:

Stroke 1. Admission. Piston travels down or out, allowing cylinder to fill with pure, fresh air from the inlet valves.

Stroke 2. Compression. Piston travels up or in, compressing air in cylinder. Compression heats the air so hot that the oil discharged into it will ignite and burn.

Stroke 3. Working down or out. At the beginning of this stroke, when the crank is on dead center, the fuel valve opens and the fuel charge of oil is sprayed into the heated air of the cylinder by a jet of air separately compressed by a small compressor. The spraying extends over 12 per cent of the working stroke of the piston, and the combustion is gradual, the resulting pressures being even and sustained, and not explosive.

Stroke 4. Exhausting. When the piston reaches the lower or outer end of the cylinder on stroke 3, the exhaust valve is opened, the pressure relieved and the piston travels up or in, driving out the exhaust gases of combustion.

LARGE DIESEL ENGINES.

Owing to the steady application of its power, the lack of vibration, comparative noiselessness, reliability and to the small space which it occupies, the Diesel engine has become an almost ideal engine for marine work where oil may be had at nominal prices. An idea of the ease with which a Diesel engine may be controlled, may be had from experiments run with the British motive ship "Eavestone." This vessel is a ship of 4,310 tons displacement recently built by Sir Raylton Dixon Company, Ltd. The 800 horse-power Diesel engine was largely built and installed by Richarsons, Westgarth & Co., Ltd., of Harthpool under the supervision of Messrs. Carel's. She was capable of doing something over 9 knots. The handling of the engines was very smart; they were reversed from full ahead to actually running astern in from 9 to 10 seconds, and this without any haste; in fact, with intentional deliberation. It was stated that the reversal had actually been completed in the remarkable time of 6 seconds. Observations showed that it only took about 3 seconds from the ringing of the telegraph till the engine was actually running ahead, the gear being already in the ahead position. Units of this character have been built for marine service up to about 2,000 horse-power single-acting type. The double-acting types are as yet but in the experimental stage.

ESTABLISHED POPULARITY OF THE SMALL DIESEL ENGINE.

The small and medium Diesel engine in sizes of 40 or 50 horse-power in single-cylinder units, up to about 600 horse-power in four-cylinder units, plays a vastly more important part in the commercial world; it has unquestionably come to stay, and has reached a high degree of perfection which places it right in line with the corresponding steam or gas engine plant as far as reliability and cost of operation are concerned, and far ahead of its competitors when considered from the standpoint of fuel economy. It is amazing to note how many manufacturers of gas and steam engines have taken up the manufacture of Diesel engines, because they found that the sale of suction-gas producer plants and smaller steam engines has fallen off alarmingly within the last few years.

The reason is plain: The single-acting four-cycle, single or multi-cylinder Diesel engine, but particularly the former, is comparatively simple in construction and operation. It does not require up-keep and attendance of boilers or gas producers, and its cost compared with that of steam or gas plant is reasonable. It can be installed in the basements of buildings below occupied dwellings. One of the greatest advantages, however, is the fact that the actual fuel consumption of Diesel engines taken over long periods of operation does not materially exceed the guaranteed figures, whereas in gas-producer and steam plants this excess is quite considerable. In a Diesel plant the human element—the skill of the operator—has much less influence upon the fuel economy than in a steam or producer-gas plant, where everything depends upon the efficiency and intelligence of fireman and producer attendant.

On account of its low cost and great simplicity and variety of fuels which can be utilized, the engines are being used and installed for various purposes; for instance: For power transmissions, for operating flour mills, for lighting factories, sanatoria, office buildings, department stores, for electrical works, etc.

Lately, they have been applied to the production of power where new and additional equipment is found necessary. It has been found that this engine can be very economically maintained as a reserve for relieving the original units of the peaks of the load and for like purposes.

The efficiency of this type of engine and its actual characteristics may be readily obtained from the results obtained from an actual test on a typical Diesel engine doing actual work. This test was conducted by A. C. Scott, Ph.D., of the Scott Engineering Company, Dallas, Texas, on a 225 horse-power Diesel engine; the following data and curves have been obtained, which will give an

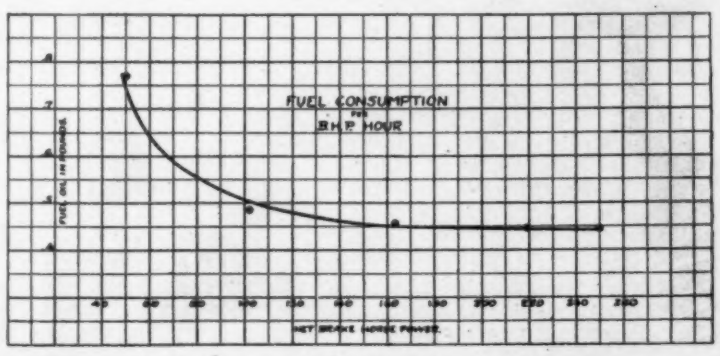


Fig. 1.

excellent idea of the applicability of this engine to the generating of power.

The engine built for the Hugo, Okla., Ice & Light Company, by the Busch-Sulzer Bros., Diesel Company, operates on the four-stroke cycle "Diesel" principle. It is a vertical three-cylinder unit, rated at 225 net B. H. P. with allowance for power necessary to drive auxiliaries. It is directly connected to a Fort Wayne 200 K. V. A. three-phase, sixty-cycle, 2,300-volt generator of 164 revo-

* Reproduced from *The Sibley Journal of Engineering.*

lutions per minute. The auxiliaries consist of one belt driver, three-stage air compressor; one motor for driving compressor, 25 horse-power; and one exciter, 10 kilowatt, speed 850 revolutions per minute belt driven from the engine.

In many cases, the air compressors for the starting and injection air for Diesel engines are belted from the crank-shaft of the engine; or when the compressor is motor driven, the power is supplied from the generator. During these series of tests, the power for compressor was furnished from an outside source. Therefore, in order to obtain the net available power developed by the engine, readings were taken of the power consumption of the motor driving the compressor and a deduction made from the kilowatt output of the generator. No allowance was made for the efficiency of the motor; so that with the compressor belted to the engine shaft, the fuel consumption per B. H. P. hour would have been less than shown in the results given.

Fuel Oil Used. To obtain the amount of fuel oil consumed by the engine, it was only necessary to weigh the oil fed to the fuel pump, where the amount of oil actually fed to the engine cylinders is automatically controlled by the governor, and varied according to load requirements. For weighing the oil a 15-gallon tank and platform scale were used, and readings were taken at ten minute intervals. A funnel of sufficient capacity was installed in order that a small amount of oil might be stored ahead of the governor, and the weighing tank properly re-filled with oil.

The oil used for these tests was taken from regular stock in ordinary use in this engine by the Hugo Ice & Light Company. Samples of oil were taken periodically, and the analysis made upon the total combined sample. The analysis of the fuel oil, made by Drs. H. W. Harper and J. R. Bailey, at the chemical laboratory of the University of Texas, is given below:

British Thermal Units	18,986. per pound of oil.
Specific Gravity (25.5 to 27 deg. Cent.)	0.8531
Viscosity 33.3 deg. Cent. (92 deg. Fahr.)	1.63
Flash Point	143.6 Fahr.
Burning (Fire) Point	181.4 Fahr.
Sulphur	0.2 per cent.
Water	Trace.
Free Acid	None.

The cost of this oil was $1.22 per barrel of 42 gallons, delivered; or practically 2.9 cents per gallon.

The instruments used in making the tests were all calibrated before using and due corrections made in the figures obtained. A water rheostat was found entirely satisfactory for the adjustment of all loads.

Tests. Six tests, each of three hours duration, were made with load changed for each hour period as follows:

Tests Nos.	1	2	3	4	5	6
Net Brake Horse-power	2.25	49.7	111.39	162.97	219.63	245.62

Fuel Consumption. The fuel consumption for these various loads was in each instance obtained from an average of the readings taken at ten minute intervals on the generator and the motor, and the records of oil used also taken every ten minutes. Fig. 1 is a curve showing in pounds the fuel oil consumed per net B. H. P. hour at the various loads. Test No. 1 is not included in this curve, as same is practically a no-load test.

This curve was plotted by taking the average readings of kilowatt output of the generator at the switchboard, corrected for the previously ascertained generator efficiency at the given load. From this was subtracted the actual kilowatt in-put to the motor and the resulting figure reduced to B. H. P. It will be noted from the above curve, that the consumption of oil per B. H. P. hour increases but very little when output is decreased from full load to about half load. At full load, the fuel consumed was 0.441 pound per B. H. P. hour, or about 6.2 gallons per hundred net B. H. P. hours. When running at practically half load, the fuel consumed was 0.482 pound per B. H. P. hour, or about 6.8 gallons per hundred net B. H. P. hours. At quarter load, the engine consumed 10.8 gallons of oil per hundred net B. H. P. hours.

Exhaust Gas Samples. Several exhaust gas samples were taken while tests were carried on. Under normal running conditions, water is turned into exhaust valve chambers, this water passing off into the atmosphere as vapor, with the exhaust gas, but whenever a sample of exhaust gas was taken, great care was exercised to shut off the water from the exhaust valve chambers, and sample was not taken until sufficient time had elapsed to insure a dry exhaust. The analyses of these gases were made by Drs. Harper and Bailey, of the University of Texas School of Chemistry, Austin, Texas, and are remarkable in that every one of the samples taken, one of each of the six tests, shows that there were absolutely no illuminants, no carbon monoxide, no hydrogen, to be found in same, thus indicating an absolutely perfect combustion of the fuel oil.

The analyses of these samples of exhaust gases are given in the third column:

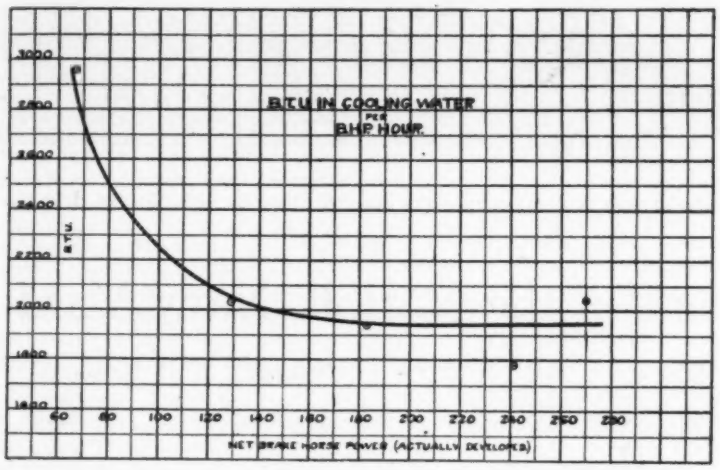


Fig. 2.

It will be noted that in some instances there appears to be an excess of oxygen, which is due to the excess of air increasing as the quantity of fuel to be burned diminishes.

Cooling Water Used. The quantity of cooling water used during these series of tests was accurately measured by a water meter, read at 10-minute intervals, and an average taken for each 3-hour test. The temperature of both inlet and outlet water was also read at 10-minute intervals, and from this was obtained the total heat carried away by the cooling water. From these figures a curve (Fig. 2) was plotted, showing the British thermal units carried away in the cooling water per B. H. P. hour.

The points plotted on the above curve were obtained by taking an average of the actual kilowatt output of the generator at the beginning and end of the 15-minute period, from which is subtracted the average kilowatt in-put to motor driving compressor over the same period, so that here again it would have been possible to show better results if the compressor were belted to the engine shaft. The purpose of these tests was to determine what

ANALYSES OF EXHAUST GASES.

	No. 1 Per cent	No. 2 Per cent	No. 3 Per cent	No. 4 Per cent	No. 5 Per cent	No. 6 Per cent
Carbon dioxide	1.50	3.05	3.92	4.70	6.46	8.40
Oxygen	18.42	16.03	14.95	14.70	9.93	8.93
"Illuminants"	.....	.....	.....	.....	.....	.....
Carbon monoxide	.....	.....	.....	.....	.....	.....
Methane	.....	.....	.....	.....	.....	.....
Hydrogen	.....	.....	.....	.....	.....	.....
Nitrogen and water vapor	80.08	80.92	81.13	80.60	83.61	82.67
Total	100.00	100.00	100.00	100.00	100.00	100.00

SUMMARY OF TESTS.

A summary of these 6 tests is given below:

Number of test	1	2	3	4	5	6
Duration of test hours	3.00	3.00	3.00	3.00	3.00	3.00
K. W. switchboard reading	.....	37.42	80.23	117.5	160	180.1
Comp. motor, gross K. W	.....	6.9	9.09	8.93	10	11.4
Net K. W. output	.....	30.52	71.14	108.57	150	168.7
Efficiency of generator	.....	85%	87%	90%	92%	92.5%
Net B. H. P. load	2.25	49.7	111.39	162.97	219.63	245.6
Speed, R. P. M.	171.1	169.1	167.4	164.4	164.8	161.9
Pounds cooling water per hour	3187	3037	4875	6300	4537	5175
Jacket inlet temp. F.	61.8	62.4	61.9	62.6	61.7	66.7
Jacket outlet temp. F.	115.3	27.9	115.5	118.9	156.6	173.1
Injection air pressure—atmosphere	39	45.6	56	59	66	77
Fuel oil—pounds per net K. W. hour	.....	1.25	0.7555	0.681	0.646	0.644
Fuel oil—pounds per net B. H. P. hour	.....	0.769	0.482	0.454	0.441	0.444
Fuel oil—gals. per 100 net B. H. P. hour	.....	10.8	6.8	6.4	6.2	6.2
Thermo-dynamic Efficiency (based upon net useful output)	.....	17.4%	27.8%	29.5%	30.3%	30.2%

efficiency might be expected under ordinary running conditions, as compared with constant conditions under steady loads. It will be noted that this curve conforms in many ways to the fuel consumption curve for steady loads, in that there is little change in the fuel consumed per kilowatt hour, between half and full load rating of the engine. The figures given on the curve are the readings as taken from switchboard meters, while points are plotted after deduction for the motor has been made.

The recovery of tin from tin-plate waste has become quite an industry. There are three general methods of separating the tin—mechanical, chemical, and electrolytic. The most important of these methods is the last. The electrolyte employed is usually hot caustic soda; loosened chips of tin-plate packed in wire baskets act as anodes, while the iron bath walls or iron plates suspended therein act as cathodes. The average tension is said to be 1.5 volts. When separated the tin is spongiform. Other methods of electrolytic de-tinning are in use in Germany, among them an alkaline method which is said to offer great advantages over the acid methods formerly used, and a chloride method applied by Lambottle of Brussels; this is the most extensively used. The principal requirements for the successful application of it are absolute exclusion of moisture during the process of de-tinning, the avoidance of an unduly high temperature, and proper washing of the de-tinned waste.

Everything in a new pigsty outside Randers, Denmark, which has two stories, and accommodates 1,500 animals, is worked by electricity. There are railway lines all over the sty, and only three men are needed to do the work, which includes grinding corn and fetching milk, foodstuffs, and young pigs from Randers.

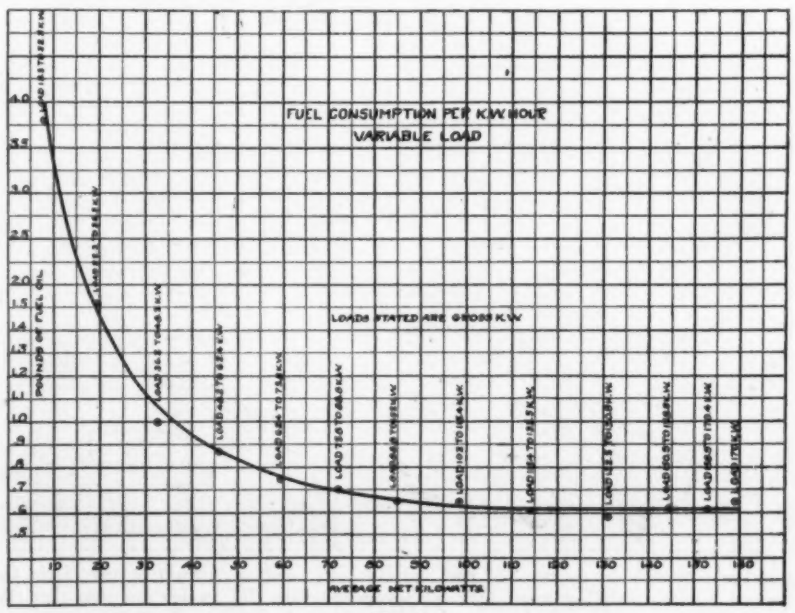
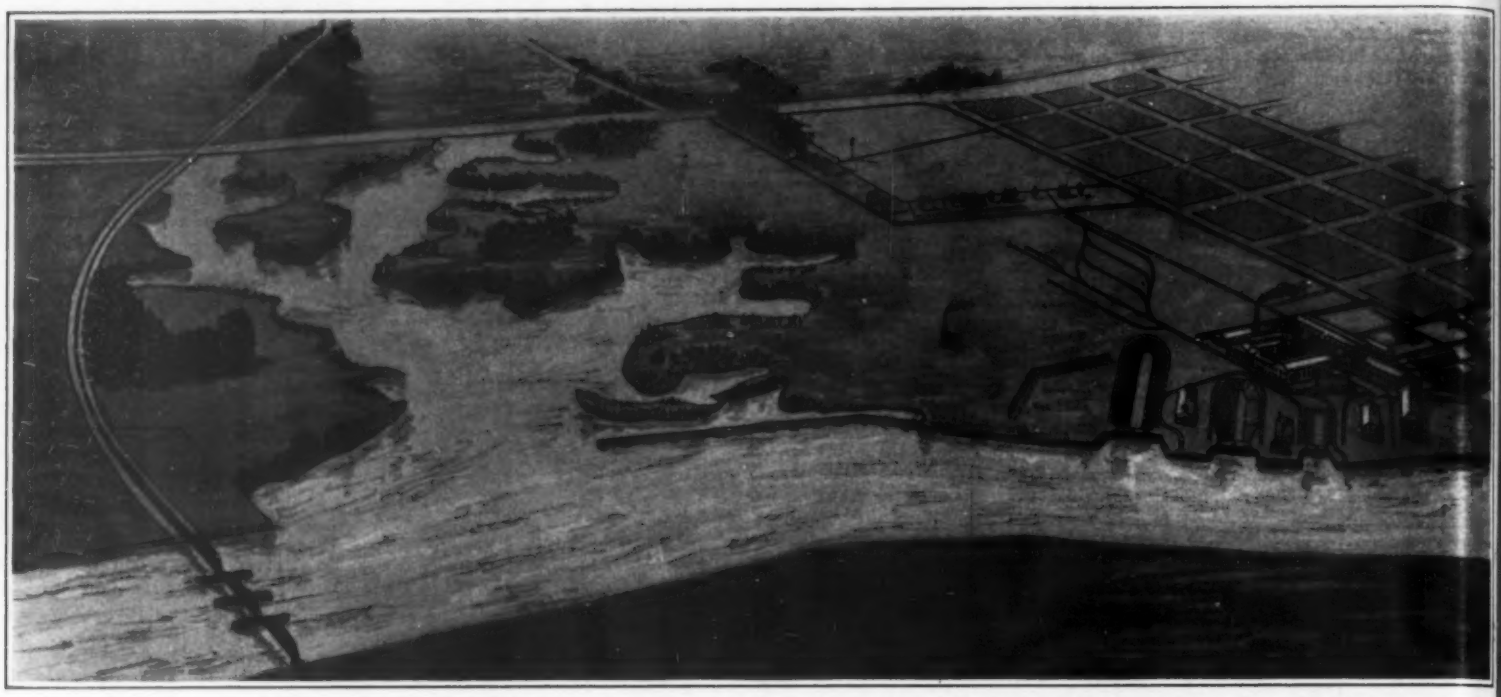


Fig. 3.



View of the undeveloped Schmoele tract to which the Doyle board proposes to apply its plan of development for the extension of the Norfolk navy yard. This tract is two hundred and seventy-two acres in extent, is about a mile long and about three quarters of a mile wide. To the right of the picture is shown a part of the present navy yard.

Proposed Enlargement of the Norfolk Navy Yard

Creating a Great Central Naval Station for Outfitting, Building, and Repairs

THE Naval Affairs Committee in Congress now has before it for consideration the plan of the Doyle board for the improvement of the Norfolk navy yard. This plan, which was conceived by Civil Engineer L. M. Cox, U. S. N., after three years of close application and study, provides the most ambitious system of drydocks, building ways, coaling equipment, and other handling machinery for naval vessels that has ever been suggested in this country.

The plan is purely suggestive. It gives in a graphic outline, with considerable attention to detail, an idea of what can be done at the Norfolk station if the Navy Department and Congress will agree upon a consistent plan of development to extend over a period of from five to ten years with an appropriation of about $15,000,000 scattered through this period.

Those who composed the Doyle board are enthusiastic over the plan, and have issued an extensive report to the Secretary of the Navy with drawings and blueprints covering the project in detail, showing facts and figures pertaining to the construction from viewpoints of labor, cost of material, transportation, manufacture, and maintenance.

The central object of interest is the drydock and the Doyle board has applied a scheme of dock building that fits in nicely with the course of the Elizabeth River, being parallel with the stream and open at both ends, equipped so that caissons may be placed at intervals in the dock to accommodate the size of the vessel to be docked, thus reducing to a minimum the amount of pumping or permitting the use of the dock for several vessels without hindering the work on those not ready to be floated.

The new type of dock has been tried abroad with success. If it be introduced here, it will be the only one of its kind on the Western continent. According to the estimate made, it is to cost $3,250,000; is to be 2,500 feet in length net; and will provide space for docking two ships of the Pennsylvania class at the same time. The board has also recommended another drydock (this to cost $3,000,000), which will enable the docking of two more ships, giving a complete docking facility of four dreadnoughts at one time. It is pointed out, however, that the second dock is purely optional and may or may not be built; but the board indicates quite clearly that it will be comparatively easy to construct the additional dock if conditions arise to require it.

The board does not want to be understood as recommending the immediate undertaking of all this work. On the contrary it submits a plan as representing its opinion of the ultimate requirements. As to carrying out the work it makes the following suggestions:

"First year, begin the construction of one drydock

This is the proposed development of the Norfolk navy yard as outlined by the Doyle board. The plan comprises an immense coaling plant (on left), a double-end drydock, building ways, berthing accommodations for twenty-one first-class battleships, and a complete system of shops, foundries, and storage buildings. The plan is suggested for the Schmoele tract which lies south of the present navy yard. Part of the present yard is shown on the right of picture.

and one building ways; the drydock to be 1,250 feet inside length with a temporary inshore end. This would require about two or three years to complete.

"Second year, begin the construction of ship fitter shop, plate, and angle storage and bending slab.

"Third year, no new work.

"Fourth year, begin dredging and sea wall and carry it to completion on annual estimate of approximately $200,000.

"The other work hereinafter mentioned should be left entirely to future development."

One of the most important features in the report is the recommendations for berthing space that will accommodate the entire Atlantic fleet. The Atlantic fleet at present consists of twenty-one modern battleships, and it is the opinion of the board that berthing space should be provided for the entire fleet as it exists today, or for 80 per cent of the fleet units if of the Pennsylvania type.

This will accomplish what no other navy yard now accomplishes. At present, Norfolk can take care of one division of the fleet with comparative comfort.

As has been pointed out in the numerous reports of naval experts, the Norfolk navy yard and Hampton Roads is a logical assembling place of battleships and is geographically located so that ships could come in for repairs, and be out on the high sea again in a comparatively short time. The fact that the Norfolk navy yard is but 21 miles from the Atlantic Ocean has been the prime argument for making the Norfolk navy yard a complete naval base.

Another departure from the beaten path is the coaling plant suggested for the extreme southern end of the tract. This plant would have a storage capacity of 200,000 tons of coal, half of which would be stored below the water line. A few hundred feet from the coaling plant are piers for supplying provisions, meats and food-stuffs of all kinds, with railroad connections which feed from the richest territory in Virginia. Further than this it is possible to bring ammunition from the magazine farther up the river to these piers. Mr. Cox stated that with this plan carried out, the Norfolk navy yard could fit out the entire Atlantic fleet ready for "business" in ten days.

As far as building ships is concerned, the recommendation is made that the Norfolk navy yard should ultimately be equipped with provision for building one dreadnought and one smaller ship at the same time, but that for the immediate future the installation of one ways and building facilities for one ship only of the dreadnought type would be sufficient. The engineers have stated that ships can be built at Norfolk navy yard at a much less cost than the Government is now paying; but in view of the fact that the Norfolk yard is not equipped for building, the first cost would be considerably higher.

The tract, which is known as the Schmoele tract, is located conveniently to belt-line connections with eight railroads. It is in about the same condition as when it was acquired by the Government some years ago. It offers an admirable plan of development, being 272 acres in extent, about a mile long, and, at its widest point, about three quarters of a mile wide. About one third of its area is under water, which will reduce the amount of dredging and excavating considerably, greatly reducing the cost.

The Mechanism of the Spring-Beetle

An Investigation of Its Method of Operation

THE common spring-beetle is an insect barely half an inch long, which, when laid upon its back, rights itself by springing into the air, often to a height of six inches. In most text-books this action is described as follows: The prostrate beetle first concaves its back by withdrawing an appendage of the head segment, known as the "thorn," from its sheath in the thorax, and pressing its point against the rim of the sheath. Then, by a violent muscular effort, the body of the beetle is bent forward, the thorn snapping into its sheath and the now convex back striking the ground with a force that hurls the insect into the air.

That this description is not entirely correct may be proved by dissecting a spring-beetle, and also by examining with a lens the insect as it lies on its back. This has been done by Dr. Otto Thilo, who describes the

Fig. 1.—A spring-beetle on its back.

results and mechanical possibilities as follows in *Umschau*: "A very accurate camera lucida drawing of the large spring-beetle (*Scmiotus*), which is about 1.5 inch long, is reproduced in Fig. 1. It will be observed that the back is only slightly hollow between the head segment and the thorax, although the thorn is retracted far from its sheath. This slight concavity vanishes when the point of the thorn touches the rim of the sheath. Hence, the upward spring of the bettle cannot be caused by the sudden reversal of a free-existent curvature. In order to discover the true explanation I investigated a lifeless mechanism, which likewise is hurled aloft by its own power.

"This mechanism is the familiar type of mouse-trap in which a wire, moved by a spring, swings through a semi-circle and strikes the mouse's back (Fig. 2). If the trap is set and one end is slightly raised and let fall, the concussion caused by striking the floor releases the catch, and the wire swings over from *b* to *b'*, striking the wooden base so violently that the trap rebounds vertically and overturns in the air. Here there is no possible reversal of curvature, and the

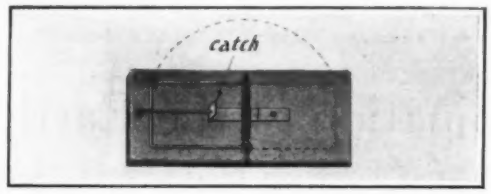


Fig. 2.—The mouse-trap experiment.

effect is caused solely by a blow on one end of the trap.

"This observation made it seem probable that the spring-beetle is similarly thrown upward by a blow on the anterior end of its body, and this view was confirmed by experiments with a working model of the beetle (Fig. 3). In this model the wire axis of the head is hinged to that of the thorax and abdomen.

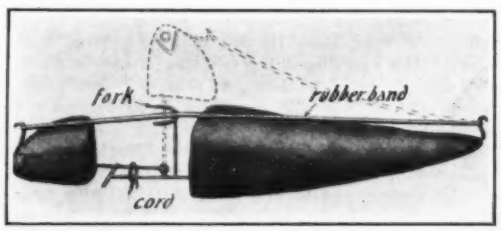


Fig. 3.—Working model of spring-beetle.

The two axes are tied together by a cord, which keeps them parallel, but when this cord is burned, the contraction of a rubber band, stretched between the extremities of the head and the abdomen, brings the axis of the head into a position perpendicular to that of the body, and causes it to strike against a fork attached to the thorax, whereupon the whole model springs into the air and overturns, in the direction indicated by the arrow.

"In order to produce a similar action in the living beetle, very powerful muscles and a very flexible joint are requisite. The spring-beetle possesses both, as I have found by microscopic examination. The movement is effected by the contraction of a pair of conspicuously well-developed muscles in the front of the neck, and it is opposed only by a pair of small extensor muscles attached very near the joint at the back. The joint is constructed in a manner which makes it very flexible.

"'The Thorn' is curved like a saber, and its entrance into its smooth curved sheath is made easier by a coat

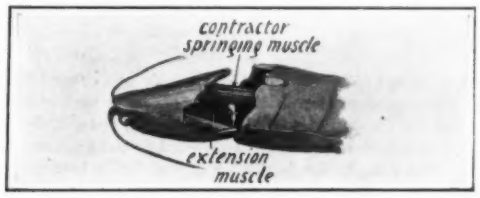


Fig. 4.—Muscles of spring-beetle.

of hair—a device frequently employed to diminish friction in the joints of beetles. We have seen that the thorn does not act as a lock or catch, for it is far from its sheath at the commencement of the action. It serves merely to guide the movement and to prevent dislocation of the neck.

"In conclusion we have to seek the reason of this peculiar action. The explanation is given by experiment. When a spring-beetle is compelled to repeat the act many times, it becomes fatigued and unable to make another spring. Then it endeavors to turn over sidewise, and usually makes many futile efforts before it succeeds in doing so. From this it appears that the beetle adopts the springing movement as the easiest method of regaining its footing. This is the popular opinion, and I find no basis for the doubt that has recently been cast up it."

Track: A Brief History of Railway Rails*

By A. B. Corthell

THE first steel rails made in this country were rolled at Danville, Pa., in 1845. Other rollings were made in the same year by the Boston Iron Works, the Trenton Iron Works, the New England Iron Company, and the Phœnix Iron Company. The first Bessemer rail made in the United States was rolled in Chicago in May, 1865; the first Bessemer steel rails to be produced on a commercial order, were rolled in Jamestown, in August, 1867. The introduction of the Bessemer process thoroughly revolutionized the art of rail manufacturing, and the ultimate effect on railway building and commercial development of our country can hardly be overestimated.

Attempts were made about 1870 to roll a combination rail with steel head and iron web and base, but the rapid reduction in price of all-steel rails rendered this process of no economic value, for while steel rails in 1872 sold for $140 per ton, in 1882 the price had dropped to $35 per ton. This cheaper production made possible the heavier rail of recent years, also the larger locomotives, greater capacity cars, and correspondingly greater economy in railroad operations. It is interesting to note in this connection that there seems to have been a fixed relation between the weight of rail in pounds per yard and the weight of locomotives in tons, for when we had 60-pound rails in general use, we had 60-ton locomotives, and with the 100-pound rail, came 100-ton locomotives; roughly speaking, in seventy years the weight of rails has increased 70 pounds, or 1 pound per year.

Not many years ago the designing of rail sections had become a fad. Most engineers were called upon to get up a new standard design, and nearly all roads had their own standard sections. As a matter of record, the rail mills at one time had no less than 188 different patterns and 119 patterns of 37 different weights per yard. The situation was investigated by the American Society of Civil Engineers, and in 1893, after more than three years' deliberation, the society reported upon standard sections for rail from 40 to 100 pounds, varying in weight in 5-pound increments. This report was accepted by the society and recommended to the railroads for adoption during the year 1901. Rails of the above type of sections constituted fully 75 per cent of all the rails rolled in American mills.

In 1901 the report of the American Railway Association recommending the use of 33-foot rails was adopted. In October, 1907, a preliminary report was submitted, accompanied by two series of proposed standard rail sections, and in 1908 the report recommended types A and B. Since October, 1907, several mills have rolled rails substantially in accord with the new sections, both A and B, and it has been demonstrated that these sections can be finished in the mill at a lower temperature than the A. S. C. E. sections. A finer grained and better wearing rail should be secured. However, great care must be exercised in the mills to

* Read before the American Society of Mechanical Engineers.

see that the rails are actually rolled at the lower temperature.

During the year 1913 there has been laid on the Boston & Maine Railroad, 500 tons of 85-pound frictionless rails in curves of 5½ degrees and over, with which it is hoped to lessen materially the flange wear on high rails, which on sharp curves is always considerable. Actual experiment shows that curve resistance is a great deal lessened by the use of this rail. The theory offered for the action of the so-called frictionless rail is based on the means that it allows the outer wheel on each axle to become dominant over the inner one, and the inner wheel to slide laterally to release the outer wheel flanges as they are forced against the outer rail. The outer wheel is traversing a greater distance through a curve than the inner one, but is making the same number of revolutions. On this account, a compensating slide of the outer wheel or a spin of the inner one must occur. The frictionless rail allows this necessary spin to occur at the inside rail.

No subject concerned with track appliances has been more discussed than that of the joint fastening. The evolution of joint fastenings has advanced through three stages: first, the chair which maintains the ends of the rail in alinement and serves as a bearing; second, the fish plate which afforded the rail some support under the head, but greatly improved the matter by stiffening the junction of the rails vertically; and third, the angle bar which combines the features of the fish plate and flange, and effected a great improvement in both the vertical and horizontal stiffness of joint fastening; the plain angle bar is very simple, easily applied, and cheap in first cost.

The conditions which bear some relation to the wear of splice bars are the extent of bearing surface and the hardness of the metal. In the new 85-pound rails and smaller sizes, the question arises whether the plain angle bar meets with the ideal requirements of the splice bar in the two important respects, strength, and the wear in the immediate vicinity of the joint which affects the close union of the parts. We know that angle bars are not strong enough, because they bend and take a permanent set in service, and occasionally one breaks. The supported joints which we have had in use are the Fisher, the Continuous, and the Weber joints.

For bolts to fasten the joints to the rails, the most efficient are those having the so-called grip thread. This bolt is made of a soft steel, and the threads are cold pressed in a manner to upset the metal so as to reduce the diameter of the bolt but slightly at the bottom of the thread. The threads are ratchet shape and undercut 5 degrees on the bearing side. In the nut the bearing side of the thread is at right angles to the axis of the aperture, so that when it is screwed tight against the splice bar the threads of the bolt give to the extent to which they are undercut, and the metal will be pushed completely to the outer recesses of the nut threads, so as to hold the nut against turning off. The nut is square with the corners chamfered next to the wearing surface, which gives an approximately circular bearing. On the bearing side the nut is recessed the depth of a thread and to a diameter somewhat larger than that of the threaded bolt, thus housing and protecting the many threads against injury by the chafing on the splice bar.

The first tie-plates were used to prevent rails from cutting into and destroying the ties. Gradual development has added other features, such as the top shoulder, spike hole, bottom claws, and ribs, all tending to make the tie-plate not only a tie protection, but a more valuable rail brace. Economy of material compels a minimum of weight consistent with strength, and one of the most important considerations is to obtain a tie-plate which will unite firmly with the tie; otherwise it will pound the tie and wear it under rail vibration and afford no lateral résistance to the spreading of the rails. As such a requirement cannot be had by a plate with a smooth underside, practically all tie-plates are now made with under projections in the shape of claws which enter the wood crosswise of the grain, or of the flanged or rib type, which enter the wood longitudinally with the grain. In the former case the lateral displacement of the plate is resisted by an abutment against an end section of the fibers. The standard Boston & Maine tie-plate has four flanges which enter the grain of the tie longitudinally, running the width of the plate. The latest tie-plate shows the two longitudinal flanges and two smaller transverse flanges on the bottom, a heavier shoulder and a better portioning of material.

Wooden ties have been almost universally used by the railroads of this country, and are still used as best practice. Steel ties and ties of concrete construction have been made and are used to some extent with varying success. For wooden ties, the hard wood tie of oak, chestnut, and hard pine are used mostly for main line traffic, and the softer woods, such as cedar, for branch lines of light service. The standard Boston & Maine tie is 6 inches thick by 8 inches wide, and 8 feet long. The average life of a chestnut tie is seven years, and hard pine ties eleven years. The life of a tie can be lengthened by the use of tie-plates and preservatives.

I can see no radical change in the present track materials or methods in the immediate future. The rail may be heavier, and more spikes, tie-plates, and braces added, but the general design will be the same. The changes in turnouts and yards will be most marked; longer switch leads, wider spacings of track, heavier rail, and more careful maintenance are already necessary in a great number of our yards, due to the increased loads in power and rolling stock. In the Pennsylvania Terminal, in New York city, we find part of the tracks laid on stone ballast and some part on a solid concrete base, with creosoted ties bedded therein and anchored by bolts to the concrete, forming a very permanent construction.

Experimental Determination of the Earth's Elastic Properties*

Apparatus and Methods Used in this Intricate Investigation

By Prof. Henry G. Gale

It is well known that the ocean tides are caused by the differences in the attraction of the sun and moon for the surface and center of the earth. These differential forces are very small compared with the attraction of the earth for bodies on its surface; in round numbers the joint tidal force of the sun and moon on a body at the earth's surface under the most favorable circumstances amounts to only about 1/10,000,000 of the weight of the body. This force would deflect the bob of a plumb line 10 feet long from its normal position only about 1/100,000 of an inch. This deviation corresponds to an angle of only 0.02 inch, or the angle which the head of a pin would subtend at a distance of ten miles.

If the earth were a perfectly fluid mass, i. e., if it offered no resistance, either elastic or viscous, to changes of shape, the surface would be tilted by the tidal forces through this same angle, and the new horizontal would be perpendicular to the new vertical. There would therefore be no change of the plumb-line relative to the earth's surface, and we could not detect the so-called "deflection of the vertical."

If the earth were perfectly rigid the plumb line would move back and forth, as the positions of the sun and moon vary, by an amount which can be calculated with an accuracy which is limited only by our knowledge of the masses and relative positions of the sun, earth, and moon. As a matter of fact, the earth is partially and not entirely rigid, and therefore the excursions of the plumb-line are a certain fractional part of the full computed value. After this fraction has been found by experiment, it is possible to compute the rigidity of the earth.

In 1879 George and Horace Darwin, at Cambridge, England, attempted to measure the rigidity of the earth. They used a heavy pendulum whose motions were greatly magnified by suspending a small mirror by two fibers very close together, one of which was fastened to the pendulum bob, and the other to a rigid support. However, even with this extremely sensitive apparatus they were unable to separate any movements due to the moon's attraction from the multitude of disturbing displacements caused by changes of temperature, earth tremors, etc.

Of these disturbing elements, a very serious one is the distortion of the land caused by the immense weight of water periodically thrown upon the coasts in the ocean tides. As late as 1898 Sir George Darwin said that he doubted if it would ever be possible to isolate the effects of the tidal forces from the multitudinous disturbances of a more or less accidental character, although he recognized a possibility in the work of Paschwitz and his successor Ehlert, at Strassburg. They had already secured encouraging results by the use of the horizontal pendulum, which is in effect an exceedingly sensitive adaptation of the plumb-line.

Since then measurements of this sort have been carried out by von Rebeur, Kortazzi, Hecker, Orloff, and others. The experimental results are so obscured by accidental disturbances, however, that their interpretation is difficult, and the results of these various observers differ widely.

In recent years Prof. T. C. Chamberlin has been much interested in the possible effect of the earth tides on the ocean tides, and he and Prof. F. R. Moulton have for years been anxious to secure some definite data on the plasticity of the earth, on account of its vital bearing on questions of planetary evolution. It was through them that Prof. Michelson became interested in the problem of measuring the elastic properties of the earth and designed the experiments which were conducted last autumn on the grounds of the Yerkes Observatory, at Williams Bay, Wisconsin. These experiments are described in full, with graphs and tables of observations, in the *Journal of Geology* and in the *Astrophysical Journal*, for March, 1914.

Prof. Michelson's idea was to substitute a long horizontal water surface for a long pendulum, and measure the changes of level at its ends. There are many advantages in this arrangement. The length may be increased to any desired extent. The water column may be entirely under ground, and thus, to a very large extent, freed from temperature disturbances. Earth tremors produce but little, if any, effect.

The arrangement actually used was as follows: An iron pipe, 500 feet long and 6 inches in diameter, was buried in a trench 6 feet deep along an accurately determined east and west line. At each end there was a pit 10 feet deep and 8 feet square, walled with concrete. The pipe was leveled, certainly to within one half inch, and probably to within one quarter of an inch, and half filled with water. A gage at each end was connected at the top to the air space in the pipe, and at the bottom to the water. A needle point in each gage was brought up from below until it nearly touched the surface of the water. The needle point was illuminated through a window in one side of the gage by a small electric flashlight. The under surface of the water formed a very perfect mirror, and the distance between the pointer and its totally reflected image was read, through a second window, with a micrometer microscope. Gages, pipes, and windows were all air-tight, so that fluctuations in barometric height at the ends were without effect. If the gage at one end was open, the image at the other was not steady, but when both ends were closed, the reflected image was as steady and sharp as the pointer itself. Microscopes were used for which a millimeter at the focus corresponded to about seventeen revolutions of the micrometer head. Observations were taken by measuring the distance between the pointer and its image at one end of the pipe, and subtracting the corresponding difference at the other end. As the water moved, e. g., toward the east end of the pipe, in response to the tidal forces, the difference (E) at the east end increased, since the water was rising higher above the pointer, and the difference (W) at the west end diminished as the water fell there. The difference $E—W$ therefore increased from hour to hour. When the water moved toward the west end of the pipe, the difference (E) decreased and (W) increased, and $E—W$ diminished. The values of $E—W$ plotted as ordinates against the time as abscissas, gave curves which represented the observed tides. Since the water moved down at one end and up at the other, and since the reflected images moved twice as far as the water surfaces, a fourfold magnification was secured. Moreover, since any change in level which might be caused by small changes in temperature or leaking altered the level at both ends alike, the errors caused by such disturbances disappeared in the double different $E—W$. Changes in level due to the settling of the pipe between the ends were also without effect. If, however, one end settled more than the other, the double difference would increase or decrease, depending on whether the east or west end settled more rapidly, and the whole curve would be given an upward or downward slope. A similar effect would also occur if there were an appreciable change in the slope of the rock strata. But since such changes were not periodic, they would not affect the result seriously.

About eighteen or twenty readings per day, at intervals of from one to three or four hours, were taken during August, and it became evident that the method was capable of yielding very accurate results. A similar line was therefore installed in a N.-S. direction

* Reproduced from *Science*.

During October and November readings were taken by the writer on both the N.-S. and E.-W. lines, with the assistance of Mr. Horace Alden of the Yerkes Observatory staff. Readings were taken once an hour from 6 A. M. to 12 P. M. and once in two hours from 12 P. M. to 6 A. M. About four minutes usually elapsed between readings at one end of a line and the other. The mean time of the two was taken as the time of the observation. The result was the same as if the two ends had been read simultaneously at the mean time. The observations began at 8 A. M., September 27th, and ended at 2 P. M., November 29th, 1913.

The curves representing the tides in both the E.-W. and N.-S. pipes were very satisfactory. They showed with great faithfulness tides of the expected form, including the diurnal inequality, and spring and neap tides. The actual change of level at each end at spring tide amounted to about 0.001 inch.

But securing these observations was not all of the problem. It was necessary to know what the tides in the pipes would have been if the earth were absolutely rigid. Computations to determine them were made by Mr. W. L. Hart under the direction of Prof. F. R. Moulton. The tidal forces acting on the water in the pipes depend on the positions of the sun and moon relative to the observer. These positions change in a very complicated manner. In the first place, the moon rises in the east and travels westward across the sky because of the earth's rotation. The moon has a motion eastward among the stars, completing a revolution around the earth in a month. Besides this eastward motion, it makes each month an excursion from 28 degrees (at the present time) north of the celestial equator to 28 degrees south of the celestial equator. Its distance from the earth varies by about 10 per cent during the month, and its eastward motion among the stars is far from being uniform. In addition to all these things the attraction of the sun on the moon causes its motion to be more irregular than it would otherwise be, and it never moves around the earth twice in the same orbit. When all of these complex changes are properly compounded with the almost equally complex ones coming from the sun, the variations in the actual tidal forces are obtained.

Fortunately the Ephemeris gives us the positions and distance of the moon and sun for every hour, thus saving an enormous amount of computation. Even with this aid the work of computing the tides in the pipes was very great. As the experiment progressed and the order of accuracy in the observations was seen to be high, it became necessary to increase the rigor of the computations. It was found necessary, for example, to take account of the fact that the tidal force of the moon is greater on the side of the earth next to the moon than on the opposite side. This refinement has not heretofore been necessary in work on the tides, but it introduces differences of as much as 3 per cent. In its final form Prof. Moulton's formula, including harmonics of the third order, took account of all factors which affected the result by as much as 1 per cent, the probable accuracy of the experimental work.

In comparing the observed and computed tides in the E.-W. pipe, Prof. Michelson found that if the computed tides were multiplied by the factor 7/10 they agreed almost perfectly with the observed ones. But the computed tides for the N.-S. pipe had to be reduced to about one half of the computed values to give the best agreement with the observations. Sample curves for the E.-W. line are given in Fig. 1, and the final mean values of the semi-daily lunar tide for both lines are given in Figs. 2 and 3. The values of the ratios finally adopted were:

E.-W.	0.710
N.-S.	0.523

These figures mean that the water tide in the E.-W. pipe was only 71 per cent of what it would have been if the earth were perfectly rigid, i. e., there is an E.-W. tide in the solid earth which is 290/710 as large as the water tide. In a N.-S. direction there is an earth tide 477/523 as great as the water tide. That is, the earth yields more readily to distorting forces in the N.-S. direction than in the E.-W. direction. Twice each day

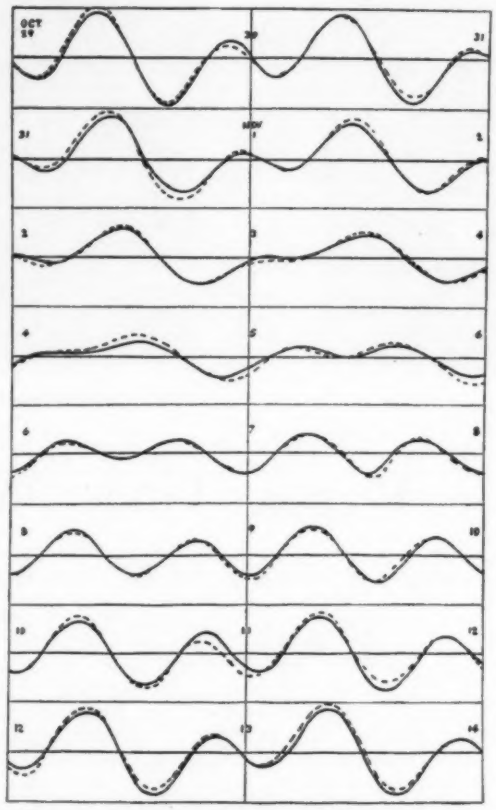


Fig. 1.—E.-W. Dotted curve, observed values; full curve, 0.7 of calculated.

the surface of the solid earth rises and falls about a foot.

This result is rather surprising, as there appears to be no simple reason why the earth should be more rigid in an E.-W. than in an N.-S. direction. The result was, however, foreshadowed by Schweydar, in discussing the observations of Hecker at Potsdam. A. E. H. Love has suggested that the effect may be due to the distortion caused by the weight of the ocean tides against the edges of the continents.

The times of high tides along the seacoasts with reference to the moon's position are, of course, very irregular, but if these enormous masses of water were flung against the coasts at the time they were due to rise in obedience to the moon's attractions, there can be little doubt that the effect would be to reduce appreciably the east and west earth tides, and thus to increase the apparent rigidity of the earth in this direction. But the ocean tides are so very complex that there appears to be little prospect of making accurate calculations on this point at present.

Added significance is given to the possibility that the ocean tides are responsible for the difference between the E.-W. and N.-S. rigidity by a consideration of the daily, instead of the semi-daily, tide. In reducing the observations Prof. Michelson found that if he considered the tide of period 25.812 hours instead of the semi-daily tide, the ratios of observed to computed amplitudes were:

E.-W.	0.72
N.-S.	0.66

The agreement here is much better than for the semi-daily tides, but as Prof. Michelson has said, if the Love-Schweydar theory is correct, we would have expected a considerable increase in the E.-W. ratio, when the disturbing effect of the ocean tides was eliminated.

Of no less importance than the ratio of the observed to the computed amplitudes is the question of their agreement in phase. It was found that the maxima and minima of the observed and computed tides occurred almost exactly simultaneously. The difference in phase furnishes a measure of the plasticity of viscosity of the earth. If there is no difference in phase between the observed and computed tides, the distortion of the earth does not lag behind the tidal forces, i. e., for any given value of the force the distortion does not tend to increase with the time. If there were a lag in the earth tide, it would throw the observed water tides ahead of the computed ones. This is rendered obvious at once by an appropriate graph. In the reduction of the observations, Prof. Michelson found that the N.-S. tides were behind the computed ones, in the mean, by about 24 seconds. This lag could have no physical meaning, and the amount is well within the limits of observational error. In the E.-W. pipe the reduction shows an acceleration of 3.6 minutes. This may be a real acceleration, but the quantity is not far from the limit of accuracy of the observations, and it is too small to be regarded as highly accurate.

The agreement of phase between the observed and computed waves is of great importance for the theories of planetary evolution. Darwin's theory of planetary fission, i. e., the breaking off of the moon from the earth and its subsequent withdrawal to its present distance, is based on the assumption that tides exist in the solid masses, which are of a viscous and not an elastic character. If tides are raised in a viscous body the protuberances are carried past the line joining the centers of the bodies and the differential pull on the protuberances acts as a brake on the motions of the system. The resulting effect is to slow down the rate of rotation and increase the distance between the two bodies. The tidal theory of the evolution of the moon depends chiefly on the assumption that such tides exist in the earth. The results of this experiment show that the earth-moon system has not undergone the evolution supposed by Darwin unless the interior conditions were formerly vastly different from what they are at present.

Prof. Moulton's calculations show that if the ratio of the observed to the calculated tides is taken as 0.70 and the acceleration of phase as the mean of the E.-W. and N.-S., i. e., 1.8 minutes, the mean rigidity of the earth is about 8.6×10^{11}, and the viscosity is 10.9×10^{16}, in C.G.S. units. These are of the order of magnitude of the rigidity and viscosity of steel. These calculations assume that the distortion decreases in geometrical progression as the time increases in arithmetical progression, and that the substance of the earth is homogeneous, a condition which does not, of course, exist. We may say, however, that the earth tides are approximately what they would be if the earth, through and through, had the properties of ordinary steel.

It would be a matter of very great interest to have similar series of observations taken at various places on the earth. Prof. Chamberlin is very hopeful that the whole problem of ocean tides, now so intricate and apparently insolvable, may yield to investigations conducted along lines which take account of the joint action of the water tide and body tide. There can be no doubt, as he has pointed out, that the tides in many places are largely influenced by the rocking of the basins. It would be necessary to conduct a number of investigations like the one herein described in different regions to give definite knowledge of the facts as to the amount of the body tide, together with an ample series of inspections of the basins of the great water bodies. Prof. Chamberlin also believes that we should have further investigations of this kind on account of their bearing on vulcanism and seismic disturbances. These phenomena are almost certainly connected with the elastic state and degree of rigidity of the earth-body and of its different parts.

It is Prof. Michelson's intention to install an automatic recording device, and to continue the observations at Yerkes Observatory by interference methods. A considerably higher degree of precision is expected.

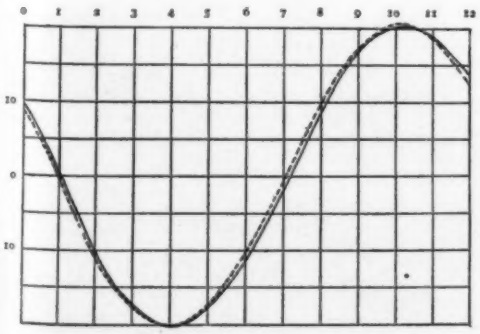


Fig. 2.—E.-W. Mean of all observations, semi-daily lunar tide. Dotted curve, observed values; full curve, 0.7 of calculated.

In Turkey, where cement is not used or hardly known, a substitute has been found that has met with rather good results when applied in exposed places, in filling crevices in water pipes, covering joints in stone floors, in fountains and for numerous other purposes where cement would be required. The mixture is as satisfactory in water as in exposed places, but it must be allowed to become thoroughly dry before it is submerged. The mixture is slaked lime, linseed oil, and cotton fiber. Generally a hollowed-out stone is used, although a flat, hard surface will answer, and the process is started by pouring the oil on a handful of cotton, after which the lime is dusted in. It is then kneaded until the whole is thoroughly mixed and about the consistency of dough. The more it is kneaded the better it becomes.

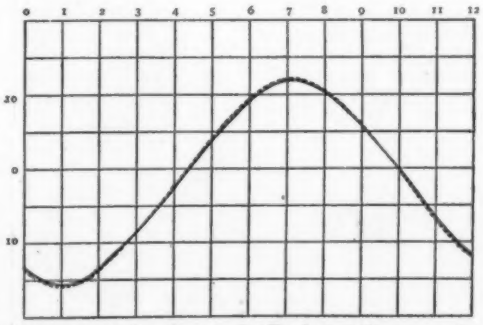


Fig. 3.—N.-S. Mean of all observations, semi-daily lunar tide. Dotted curve, observed values; full curve, 0.5 of calculated.

The working chamber from which the pictures were taken.

On board the working barge. The operator about to descend.

Moving Pictures Under Water

A New Apparatus for Making Sub-Marine Investigations

By Keville Glennan

EXCEPT from the lips of divers who have descended on the edges of the coasts to a puny depth of a hundred feet, we are in ignorance of what lies beneath the waves. And the divers, with the limited field of observation accorded them by the crude appliances of their trade, have been able to tell us but little of the nature of things in that vast area beneath the waters which embraces three fourths of the earth's surface.

Now the riddle of the deep is about to be solved. For hours at a time men have sat in comfort fifty or sixty feet beneath the surface, where they have smoked and talked and breathed as naturally as though on shore. And they looked with delight at the wonders and beauties of subaqueous forests; studied the thousands of brightly colored tropical fish; watched with increasing admiration and surprise the panorama afforded by the lacelike lengths of a coral reef, and observed with awe the skeletons of once proud ships as they rested where they disappeared from human ken generations ago.

What these men saw beneath the sea they photographed, and some of the wonderful pictures they secured are here reproduced, giving to the readers of this publication the first authentic motion-picture views ever taken in the depths of the ocean.

While it is true that the greatest depth achieved in these experiments is not greater than that frequently reached by divers, it was demonstrated that a means for deeper trips into the unknown waters has been found, and that the time is not far distant when it will be easy to go down several hundred feet. The apparatus used in the experiments was subjected to a thorough examination at the Norfolk navy yard by officers of the navy, who reported that it would be perfectly safe in its present form of construction at a depth of 800 feet. To make it strong enough to go even deeper is simply a mechanical detail.

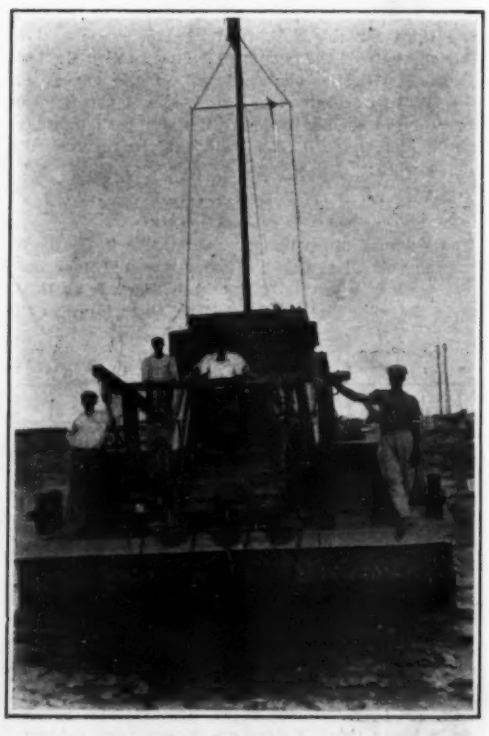
A diver at the bottom of the sea.

The experiments in the waters of the Bahamas were made to secure a scientific motion-picture film that would show the actual conditions on the bottom of the sea, and the daily habits of the many forms of sea life that abound in the waters of the tropics. Before describing the way in which the photographs were secured an outline of the apparatus used will give an insight into the mechanical features of the experiments.

Several years ago Capt. C. Williamson of Norfolk began working to perfect an invention that would take the place of the ordinary diving suit. It was his idea that some means should be developed by which a man could go down into the water unhampered by weights, ropes, compressed air, or water pressure. Broadly considered, his apparatus is in three parts: (1) a floating vessel of any suitable design; (2) a submersible terminal operating chamber in which work or observations can be carried on at the bottom of the water; and (3) a collapsible, flexible tube of metal connecting the floating vessel and the submersible chamber.

The main feature of the invention is the tube which is made of steel sections of varying lengths. Each section has an upper and lower flange and these are connected by a set of steel hinges, so arranged as to open and shut along radial lines to the axis of the tube, but at all times to fit against each other so closely as to be water-tight. Some of the sections have only one set of hinges and when collapsed the flanges rest upon each other. In the longer sections there are several sets of hinges joined to each other between the upper and lower flanges. When collapsed they stand about three feet high, and are eight feet long when extended. The sections can be fitted to each other readily, and the length of the tube thus regulated as required. Because of the collapsible nature of the sections it is possible to easily submerge the tube. Anyone who has tried to push a large bucket bottom downward into the water will realize what a difficult thing it is to do. With the collapsible tube each section displaces a little less than its own weight in water at the surface when extended; therefore it will sink. But deeper down the pressure of the water overcomes this advantage, when the tube automatically collapses, section by section, from the bottom upward, and as each section closes its weight remains the same, but its volume of displacement grows less. By this means the continual adding on of sections at the surface forces down the sections

Fish around a baited hook.



The diving barge.

below. The operating chamber is attached to the bottom section.

The idea of taking submarine motion pictures came to the sons of the inventor while watching the projection of a scientific film showing fish swimming in a small glass aquarium tank. These two boys, J. Ernest Williamson and George M. Williamson, had worked with their father in the development of the tube, and they at once set about arranging experiments, and in a few weeks had secured excellent snapshots of fish swimming along the bottom of Hampton Roads with an ordinary camera.

Using these photographs as an argument, they formed a corporation for the purpose of making photographic records of the ocean's bottom. So far 20,000 feet of marvelous film pictures have been taken beneath the ocean in the West Indies.

The Williamson boys designed a special chamber for the photographic work and also drew the plans for a vessel from which to lower the tube and chamber. This chamber is a hollow sphere of steel with an inside diameter of 5 feet, and from it a cone of steel 5 feet long and 5 feet in diameter at the large end projects horizontally. This cone penetrates the sphere, and at its small end, where it is 18 inches in diameter, a steel bulkhead is fitted. In this bulkhead there are two glass ports, 3 inches in diameter, placed one above the other, which are the eyes of the photographer and the camera. The large end of the cone is closed by a piece of plate glass 1½ inches thick, which was manufactured in Germany especially for the purpose, and is optically flawless.

To protect this glass from the pressure of the water, gages and pumps were installed in the sphere. One gage shows the water pressure against the outside of the glass. The other shows the air pressure within the cone, and the pump is used to equalize these pressures. In the sphere the air is the same as that above the water, and the photographer works under the same conditions he would experience were he photographing the inside of a building.

It was the original intention that the first pictures be taken on the Pacific Coast, but upon the advice of Dr. Townsend, curator of the New York Aquarium, the Bahama Islands were selected as being richest in varied forms of marine life and variegated corals, and the waters of unexcelled clearness.

The first film was made in the celebrated Marine Gardens at a depth varying from fifteen to twenty-five feet. These gardens are in a narrow strait between Hog and Athol Islands, and as a strong current of about seven knots an hour is constantly running through this channel, it was just the place to give the tube a severe test at the very beginning of the work, and the result was eminently satisfactory. By mooring the barge to four anchors across the tide, and then slacking the cables on one side and taking in those on the other, it was possible to swing with the tide while Mr. Gregory, down in the chamber, turned the crank of his camera and photographed a panorama of sea bottom wonderful in the luxuriant growth that makes the Marine Gardens so beautiful and unlike anything that can be found above the surface of the waters. The clearness of the water and the perfect illumination afforded by the sunlight coming through it and striking the white coral bottom was remarkable, and in the deep recesses of the coral caverns it was not unusual to secure perfectly exposed negatives at 1/75th of a second with a lens opening of f6.3.

Not only are the Marine Gardens there more beautiful than any in this part of the world, but there are many wrecks strewn along the treacherous coral reefs which extend for miles along these islands, for here in the old days many a Spanish galleon and treasure ship and many a Spanish conquistadore came to grief.

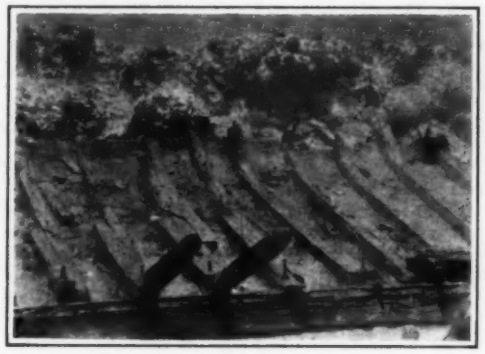
In the shipyard at Nassau the Williamson boys had constructed a barge about forty feet by eighteen wide, in which was built a well of sufficient size to permit of the passing of the observation chamber, which was handled by chain hoists.

The Williamson brothers took charge of the entire outfit and its operation, but they secured Carl L. Gregory, an expert photographer, to make the first photographic film ever taken beneath the ocean, and to these three young men is due the wonderful success of the undertaking.

Photographing under and through water presents many new problems, as density and light values had to be studied carefully to insure proper focus and exposure. But prior to starting work with the camera Mr. Gregory and the writer prospected the waters near Nassau with a glass-bottomed boat, buoying locations of unusual beauty as well as a number of old wrecks lying on the sharp coral reefs, and several deep caverns that were inhabited by thousands of brightly colored fish.

The barge was named the "Jules Verne," in honor of the writer whose imagination saw what the camera has now revealed, and it was a coincidence that the powerboat that towed it was named the "Nautilus." Superstitious ones at once decided it to be a good omen.

When looking down into the water by means of a



Hulk of a sunken blockade runner.

water-glass the vegetation at the sea bottom is much foreshadowed, and the greatest height is, seemingly, about three feet. Through the glass of the chamber, however, the beautiful ferns, sea palms, and other

Diver preparing to descend in an ordinary diving suit.

species of subaqueous growth are seen in their full dignity as they wave and sway in the tide to a height of eight or ten feet.

For the first time photographs were taken of a deep-sea diver working on a wreck. Near Nassau there is the hulk of an old blockade runner that came to grief during the Civil War, lying at a depth of fifty feet; and scattered on the bottom near her are some rust-encrusted cannon and many cannon balls. George Williamson volunteered to be a diver, and although he had never been beneath the surface in this sort of garb before, he gamely went down and strolled about the wreck, picking up cannon balls and sending them aloft in a wire basket attached to a line, and while so engaged, Mr. Gregory, safe and dry in the chamber, was photographing him.

How the pictures were taken.

Another interesting film was made to show the entire workings of the sponge industry. The fleet of a hundred or more sponge schooners was filmed at the quay in Nassau. The barge was then towed out to the sponge bottoms, and the chamber lowered where a full view of the sponges could be had. Instead of diving, the spongers use a bucket with a glass bottom, through which they can look down into the water. When they see a sponge they push down a long pole with two iron hooks on its end, twist the hooks into the roots of the sponge and pull it from its bed on the bottom. This process was photographed, both below the water and on the deck of the sponge boat, and the marketing and trimming of the sponges on shore followed.

Many feet of film were made of the hundreds of different kinds of fish that abound in the Bahama waters. Some were caught as they swam about in their natural haunts among the coral reefs, and others were lured close up to the chamber by means of a baited line. Color plates were taken to be used as a guide in coloring the film by hand, so that the world may see in their natural tints the fish, the wrecks, the reefs, and the marine gardens.

As in all tropical waters, the sea around the Bahamas abounds in sharks, and a film was secured of a battle between two of these monsters. Specimens eighteen and twenty feet long are common and no ordinary sized bait would last long enough for the purpose of photographing them.

However, after unwinding many miles of British red tape, for the law does not permit an animal to be wantonly killed no matter how incapable of work it may be, a lame horse was secured and put to death by a special agent from the Police Department, at a convenient place on the shore, from whence it was towed out to sea and anchored in the water near the apparatus. In less than an hour after there were twenty to twenty-five of these huge scavengers of the sea milling around the bait.

Half a dozen of these monsters were caught with large hooks attached to chains, and one of the largest was drawn to the chamber to permit the taking of a good view of his struggles. A portion of the hunch of meat which was used for bait still protruded from his jaws, and while he struggled thus, another huge shark swam in view and wrested it from him. Swallowing this at a gulp, the newcomer swerved away a few feet and then turning with open jaws, darted like an arrow at the fish still imprisoned by the hook. A battle royal followed, each lunging with open mouth, and tearing one another at every available point, but despite the hook which still hung tenaciously to his jaws, the wounded shark beat off his opponent. Every movement of this unique battle is faithfully recorded on the film.

Many stories have been written of hand-to-hand conflicts between men and sharks, but when it comes to finding a native diver who will actually go down armed with nothing but a short knife, and engage in a single-handed combat with one of these brutes, it means considerable more than the exercise of a fertile imagination. Such a man was at last found, and motion pictures made of a naked diver meeting one of these kings of the deep in his own element, and, escaping the yawning jaws as a matador dodges a bull, with one swift thrust quivering steel landing a death stroke in the monster's vitals.

A New Element in the Atmosphere

By F. W. Aston

In his studies on the positive rays, J. J. Thomson obtained indications of the presence in the air of a body of atomic weight about 22 and giving a line next to neon, atomic weight 20. On continuing this work the conclusion is reached that atmospheric neon is a mixture of two gases which are identical in all their properties except their atomic weights, which are, respectively, 19.9 and 22.1. By 3,000 fractionations of the gas, or, better, by using the diffusion method in conjunction with a new quartz-disk density balance in which 0.5 cubic centimeter of the gas is weighed against oxygen, it is found that ordinary neon contains about 12.5 per cent of the heavier gas, which does not appear to be a compound. The spectra of the two gases are apparently identical.—*Engineering.*

The Flying Machine from an Engineering Standpoint—I*

A Review of Recent Progress

By Frederick William Lanchester, M. Inst. C. E.

1. *The Air Considered as the Permanent Way.*—In approaching the subject of the flying machine from the engineering standpoint, it is desirable to devote attention in the first instance to the air considered as the "permanent way." When the atmosphere is quiescent a gliding model or a flying machine carves its way through the air in rectilinear flight as if supported on a perpectly laid track—a far more perfectly laid track than the railway engineer has hitherto shown himself able to lay down. Under such conditions the aeronautical constructor requires to know the weight and coefficient of traction of the machine, the velocity of flight, and the maximum gradient it is required to climb, the problem then resolving itself into the provision of a screw propeller of sufficient diameter and appropriate pitch to supply the necessary thrust reaction, and the fitting of a motive-power engine (and, if necessary, gearing) to drive the said propeller at its correct speed. The horsepower needed is calculated just as in any other case of propulsion or traction. In addition, the engineer needs to be able to calculate the stresses necessary to the design of his aerofoil and fuselage structure, and to design a suitable alighting chassis. For the present, we shall assume that we have to deal with a machine in being, and devote our attention to the peculiarities and properties of the aerial highway to which the machine has to be adapted and to adapt itself. In Fig. 1 is represented the flight path[1] of a hypothetical machine, plotted from a mathematical equation. The hypothetical machine differs from an actual flying machine, or glider, inasmuch as it is assumed to be quite small in comparison to the minimum radius of curvature of its flight path; its whole mass is taken as concentrated at its center of gravity (consequently it has no moment of inertia about its transverse axis), and it is presumed to experience no resistance in flight, or, alternatively, it is supposed to have a propelling force constantly applied equal at every instant to its resistance. Referring to Fig. 1, it is seen that the straight-line flight path is represented by a horizontal line, path No. 1; here the velocity of the machine is equal to that acquired by a body falling freely through a distance H_n constituting the distance between flight-path No. 1 and the datum line. For this hypothetical machine there is an infinite number of other possible flight paths, the whole series being represented by the equation:

$$\cos\theta = \frac{H}{3H_n} + \frac{C}{\sqrt{H}},$$

from which the samples given are plotted.

It will be seen that the series comprises two notable special cases;[2] first, we have the straight-line path No. 1; secondly, the exact semi-circle No. 7.

The flight paths, or "phugoids," Nos. 1 to 6, of less amplitude than the semi-circle, are those which are of chief concern from our present point of view, the cases beyond the semi-circle, in which the curve has no point of inflection, and in which the machine "loops the loop," are in the main only interesting from the point of view of the mathematician and the student of "trick flying." These inflected curves have been more fully plotted in Fig. 2. In both Figs. 1 and 2 the velocity at any point is that corresponding to a body falling freely from the datum line. Thus, given the normal or natural flight velocity V_n, the scale of the chart is determined by the calculation of H_n from the equation of the falling body,

$$H_n = \frac{V_n^2}{2g}.$$

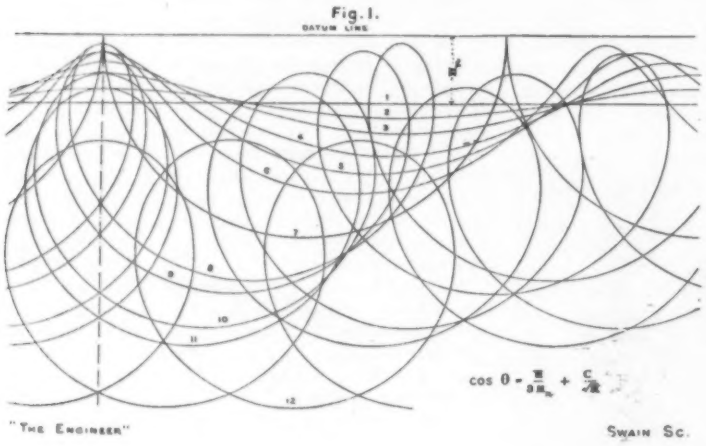
Although, as already stated, the flight paths given in Figs. 1 and 2 represent, strictly speaking, a hypothetical machine that only faintly resembles an actual machine, the difference has but little effect on the validity of these flight-path charts. I have shown[3] that in the main the effect of moment of inertia about the transverse axis is to cause the amplitude of the oscillation to increase, so that the machine, or glider, will pass by imperceptible stages from one curve to another in the order they are numbered on the chart, eventually leading to instability. I have also demonstrated that the assumption of a constant horizontal propulsive force, in place of a force always in equilibrium with the resistance, has the reverse effect, and tends to damp out an oscillation and diminish the path amplitude. We may thus in any free-flight model, or glider, have the flight path unstable, neutral, or stable,[4] according to which (if either) influence predominates. In an actual flying machine we may also have the flight path unstable, neutral, or stable; but here experience has shown that a skilled pilot is well able to handle a machine even though its natural flight path may be unstable; in spite of this, calculation shows that, speaking generally, machines as flown to-day are not far, one way or the other, from the neutral state. From the engineer's point of view it is unimportant whether the flight-path stability is inherent in the machine, or whether, so to speak, the finishing touches have to be given by the pilot himself.

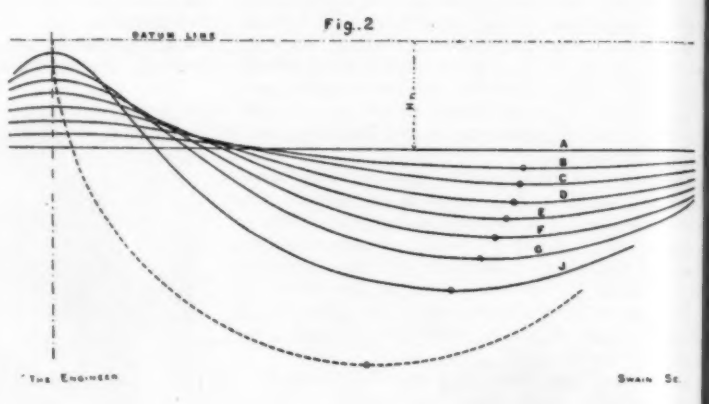
The point I wish to make clear at the present juncture is that the curves, plotted from a mathematical equation, do actually apply with reasonable experimental exactitude to models and to machines in flight. Thus, a disturbance acting on any model in free flight will set up periodic undulations in the flight path, and these have, within the limits of experimental observation, both the time period and phase length corresponding to their theoretical values in relation to the flight velocity. Some experimental determinations,[5] showing the reality of this relation made with models in free flight, are given in Table I.

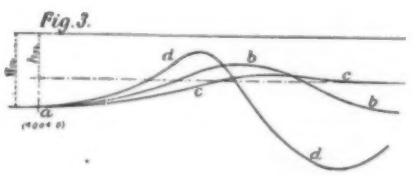
TABLE I.

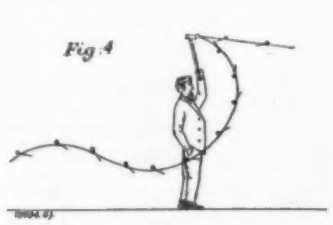
	1	2	3
Flight velocity	14.0	14.0	10.0
Theoretical phase length, feet	27.0	27.0	15.1
Measured phase length, feet	26.0	.....	.....
Theoretical time period, seconds	1.93	1.93	1.5
Measured time period, seconds	1.9	1.83	1.3

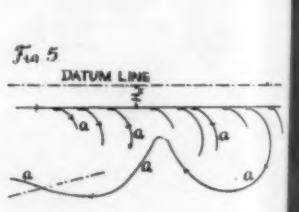
The phugoid, or flight-path chart, is capable of use-

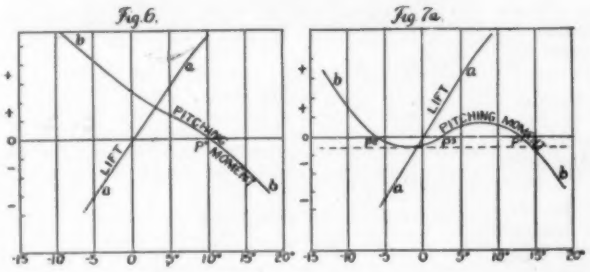


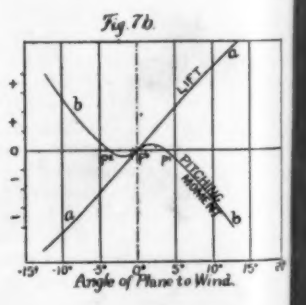












* The James Forrest lecture, delivered before the Institution of Civil Engineers on May 5th. Compare also the same author's paper on "Catastrophic Instability in Aeroplanes," SCIENTIFIC AMERICAN SUPPLEMENT, February 14th, 1914, p. 98.

[1] Reproduced from Fig. 42 of "Aerial Flight," by F. W. Lanchester, vol. ii.

[2] There is a further special case when the value of H becomes infinite; the flight path becomes a circle of radius $= 2H_n$.

[3] "Aerial Flight," vol. ii, § 52 *et seq.*

[4] This kind of stability is frequently termed "dynamic stability."

[5] Tabulated from "Aerial Flight," vol. ii, § 69.

application in more ways than one. Any movement of the tail-plane or "elevator," for example, by altering the attitude of the main aerofoil causes the machine to become self-supporting at a lower or higher velocity; that is to say, alters its natural velocity, and we thus may represent such a change in the manner indicated in Fig. 3. Here a machine is presumed flying at a certain velocity corresponding to the height H_a, its elevator at the point *a* is altered to correspond to a lower flight velocity corresponding to a height h_a; this is equivalent to altering the scale of the chart at that point, and the subsequent path of the machine is represented by the phugoid curve *ab*. This path may undergo damping, either due to the inherent stability of the flight path, or due to the intervention of the pilot, as shown by the line *ac*. In the case of a model of unstable flight path, with no intervention from the pilot, the flight path becomes one of augmented amplitude, *ad*.

When a machine is fitted with an elevator (or adjustable tail-plate) of large surface, it is possible for the pilot to take such entire charge of his machine that he appears to be designing his own flight-path curves rather than modifying or damping the natural curves of the equation. It is quite true that this is one way to fly; it is, in fact, the old Wright method of flying, the original Wright machines having been furnished with a front elevator carrying little or no load. That type of machine, however, may be regarded as a thing of the past. The Wright machine could be "piled up" by inattention or want of skill at any moment, and if once its flight velocity fell below a certain value, either from want of attention on the part of the pilot, or from a wind-gust from abaft, or other cause, the pilot was definitely unable to restore his normal flight condition; it is for this reason that the Wright type of machine has been abandoned.[6]

2. *Catastrophic Instability.*—Before entirely quitting this branch of the subject, attention will be directed to a point first raised by me within the last twelve months, under the title of "Catastrophic Instability." It is a curious fact that, although the author and other investigators had been studying the question of stability by various methods for some twenty years more or less, and such items as longitudinal stability, lateral stability, and a form known as asymmetric or "rotative" stability, have been "catalogued" and investigated, both theoretically and experimentally, a form of instability which may in practice be far more serious and deadly has until quite recently escaped notice. There are certain types of flight model, of which the ordinary "ballasted plane" is an example, in which the flight path is ambiguous. In the case of the ballasted plane[7] the position is quite simple; this type of model is symmetrical, it has no "upside down"; if launched at its correct flight velocity to travel on flight-path No. 1 (Fig. 1), it is equally capable of traveling on an alternative flight path intermediate to those numbered 11 and 12, the only determining factor being whether at the moment of launching the pressure reaction is in an upward or a downward direction. A very slight want of skill in launching one of these ballasted planes gives at once the inverted flight path (Fig. 4); likewise a gust or disturbance acting on a model of this kind in flight may be sufficient to invert the flight path and determine its downfall. From our present point of view, regarding the air as the "permanent way," the position is as though the model, or machine, were continually crossing a number of facing points arranged, not quite as on a railway, but in a vertical sense (Fig. 5), so that the machine is always in danger of being switched off to an inverted flight path *aa*, if an aerial disturbance of the right kind and sufficient magnitude and duration happen to be encountered.[8]

In my opinion the soundest way to avoid danger from this cause is experiment in a wind channel with scale models, both of the aerofoil and of the machine as a whole, prepared from the working drawings.

According to the evidence that has up to the present been collected, the lift diagram for any machine passes without break of continuity from positive to negative values, and the angle of inclination is a single-valued function of the pressure reaction *aa*, Figs. 6 and 7*a*. The pitching moment in some cases is a curve of similar character, *bb*, Fig. 6, in other cases it is of the form *bb*, Figs. 7*a* and 7*b*, the latter of which represents the case of the ballasted plane. In Fig. 6 the model may be considered as catastrophically stable, but in Figs. 7*a* and 7*b* there is instability; there are three positions, or attitudes, of the machine at which the pitching moment is zero, the two outer two, p_1 and p_3, defining, respectively, the stable positions of normal and upside-down flight, and p_2 marking the critical angle of unstable equilibrium when the machine passes from one state to the other.

In Table II are given results of some experiments recently carried out with a model machine at the National Physical Laboratory. These were not directed to the point in question, but incidentally serve as an apt illustration, and roughly from the basis of the plotting, Fig. 7*a*.

TABLE II.

Angle of Pitch.	Pitching Moment.	
chord as datum		
−14	+0.0264	
−12	+0.0152	
−10	+0.0063	Angle of stable equilibrium upside down.
− 8	−0.0015	
− 6	−0.0059	
− 4	−0.0049	
− 2	−0.0014	Critical angle of catastrophic change of flight path.
0	+0.0030	
2	+0.0070	
4	+0.0102	
6	+0.0210	
8	+0.0218	
10	+0.0127	
12	+0.0072	
14	+0.0026	Angle of stable equilibrium right way up.
16	−0.0043	
18	−0.0173	

In the experimental figures as tabulated, the evidence of catastrophic instability is seen in the column headed pitching moment; whenever there are three changes of sign the model is catastrophically unstable.

(*To be continued.*)

Pressure of Light Measured by Use of Thin Foil

By G. D. West

THE pressure of the radiation emitted by a carbon filament lamp at a distance of a few centimeters is sufficient to cause a microscopically measurable deflection of the end of a suspended strip of gold, or aluminium foil, and by this means the radiation pressure can be calculated if the weight of the strip is known. The results agree to within about 10 per cent with the energy density of radiation as measured by the initial rise of temperature of a copper plate exposed to the radiation. The best results are obtained by working in an atmosphere of hydrogen, at 1 centimeter to 2 centimeters pressure, but good results are obtained with hydrogen at atmospheric pressure. Air at 1 centimeter to 2 centimeters pressure also gives good results. The method involves no laborious adjustments, and the apparatus is not seriously affected by vibration.—*Phys. Soc. Proc.*

Neutralization of Chromic Acid

By L. Margaillan

THE progressive neutralization of chromic acid by sodium hydroxide was followed by the electrometer method, using an electrode of platinum saturated with hydrogen. The E. M. F. curve was interrupted by two almost vertical portions (instead of one, as with sulphuric acid), corresponding respectively to the addition of one and of two equivalents of alkali.—*Comptes Rendus.*

[6] Practically the whole of the distinctive features of the early Wright machine have disappeared to-day; for example, the tailless machine is a thing of the past, nearly every modern machine is fitted with a tail-plane. The forward elevator is obsolete or nearly so. The twin propeller has given place to the single propeller in almost every case. The gear-driven propeller has also been abandoned. The vertical four-cylinder or motorcar type of engine has proved itself inadequate. The exposed position of the pilot, engine, etc., has gone never to return. The Wright method of launching on runners and alighting on skids also is a thing of the past. The biplane construction of the fore-and-aft vertical surface has to some extent survived, but these features were in no wise new when adopted by the Wright Brothers. The wing warping and vertical rudder (neither feature in itself new), operated by the Wright Brothers from one control lever in common, are nowadays operated from two entirely separate controls.

[7] A rectangular plate of mica, conveniently 0.003 inch thick, 8 inches by 2 inches, ballasted at the center of the leading edge. Compare "Aerial Flight," vol. i, p. 231; vol. ii, p. 4.

[8] The disastrous nature of this sudden inversion of the flight path may be gaged from the fact that it represents in effect a complete reversal of gravity, the machine is accelerated downward with a force comparable to that previously giving it support, and any loose tools, instruments, or fitments, including the pilot himself, are liable to be jettisoned by the machine, whose subsequent career is an upside down flight carried out on its own account. The facts on record relating to the fatal accident to Major Merrick at the Central Flying School (October 3rd, 1913) point strongly to catastrophic instability as the cause.

The Lassen Peak Eruptions

Are They a Renewal of Volcanic Activity?

WITH the devastating effects of the San Francisco earthquake still fresh in mind, the eruptions on Lassen Peak, California, are exciting considerable interest, especially on the Pacific Coast. As is well known, a wide area of country that includes portions of California, Oregon, Washington, and Idaho was once a vast volcanic field, and the present eruptions on Lassen, which was once an active volcano, raise the question whether they are of a volcanic nature, and therefore a menace to the surrounding country. So far there do not appear to have been any particularly alarming symptoms; but as J. S. Diller, a prominent geologist, says in a report to the U. S. Geological Survey, Washington, "time alone can tell."

"Mount Rainier and Mount Shasta, the beautiful cones so much in evidence to the traveler on the Pacific Coast north of San Francisco, are now finding an up-to-date rival in Lassen Peak, which is plainly in view from the railroad for many miles in the Sacramento Valley between Redding and Red Bluff. Lassen Peak is the southern end of the Cascade Range, and it stands between the Sierra Nevada on the southeast and the Klamath Mountains on the northwest. Its lavas erupted in past ages reach the Sacramento Valley on the one side and on the other form a part of the vast volcanic field, one of the greatest in the world, that stretches far across California, Oregon, Washington, and Idaho to the Yellowstone National Park.

"Of all portions of the Cascade Range Lassen Peak still retains the largest remnant of its once vigorous volcanic energy. Morgan and Suppan Hot Springs and Bumpass Hell on the south as well as Hot Springs Valley and the boiling mud-lake Tartarus on the southeast have long attracted the attention not only of Californians but to some extent of the tourists, to whom the region is growing more accessible every year. If to these already established attractions be added a frequent occurrence of the recent volcanic plays of Lassen Peak the region will take high rank among Nature's wonderlands.

"But what is the nature of this new activity of Lassen? Is it really volcanic? Will it soon dwindle and become wholly quiescent, or, on the other hand, is it the precursor of a more profound eruption like that of Krakatoa? The excellent photographs that have been taken of the outburst, from a point six miles northwest of Lassen Peak, leave little doubt in the mind of anyone familiar with volcanic phenomena that the outburst is essentially volcanic. These photographs are strikingly similar to those taken by Johnston-Lavis showing the progress of an eruption in the Lipari Islands, whose volcanic character is well known.

"The eruptions of Lassen Peak began May 30th at 5:30 P. M., with an outburst of steam which, according to Forest Supervisor W. J. Rushing, continued about ten minutes. It formed a crater in the snow-covered summit of Lassen about 25 by 40 feet in extent and covered the encircling snow for a distance of 300 feet with a mantle of dark wet dust. Harvey Abbey, a forest ranger, visited the scene and reported the facts.

"On the following day at 8 A. M., another eruption occurred, and on June 8th, a week later, the third and much larger outbreak took place. It lasted 30 minutes, and the rolling column of dense black smoke rose to the height of 2,500 feet. Stones were hurled from the crater, and the forest service outlook house, a quarter of a mile away on the tip-top of Lassen Peak, was broken by some of them. Blocks and smaller fragments accumulated about the crater to a depth of several feet. The dust and sulphurous gases carried southward by the wind were observed at Mineral, the forestry station, and the dust was noted five miles beyond. Forest rangers who were in the neighborhood of the summit during the eruption heard the rushing steam and the falling rocks, but report no rumbling or subterraneous noises, earth shocks, electrical phenomena, or great heat beyond that of steam. The dust was practically cold when it fell. Considerable volumes of water were ejected, probably wholly in the form of steam. The water condensing from this steam washed a gully in the snow to the adjacent lakelet which occupies what prior to this latest eruption had long been regarded as the youngest crater of the Lassen volcano. The new crater is not quite over the throat of the old, but is a few hundred feet to the northwestward.

"In all there have been eleven eruptions up to the date of this report—June 21st. The most violent was at 9 A. M., June 14th, when several over-venturesome persons were injured by falling or rolling stones. The eruption was visible from the Sacramento Valley, nearly forty miles away, and created profound interest. The subsequent eruption on Friday, June 19th, was of relatively small energy. Eruptions were generally preceded by a cessation of escaping steam.

"With successive eruptions the new crater is enlarging. June 20th, when Mr. B. F. Loomis and I visited it, it was 400 feet long and 100 feet wide, with a depth of not over 100 feet. It appears to follow a fissure running a little north of east and south of west.

"The other hot holes about Lassen Peak as far as I

can learn have not increased their activity, unless it is Bumpass Hell, which is always fuming; but nothing like an eruption has been reported.

"No definite molten products have been found in connection with the recent eruptions of Lassen Peak. The ejected dust, as far as can be judged from an examination with a small pocket lens, is disintegrated or pulverized dacite, perhaps in part decomposed. The quartz and, apparently, also the glassy feldspar are bright, but the hornblende, augite, and mica are of course not so abundant in the dacite and are less evident. An examination with a petrographic microscope confirms the conclusion that the dust is the product of the pulverizing action of the explosive gases on the rocks through which they are escaping, and not the result of the explosive expansion of gases in a liquid lava.

"That heat has recently risen in the core of Lassen Peak is evident from the fact that whereas it was once cold, now it is hot and steaming. When E. E. Hayden and I were on the mountain in July, 1883, and slid down the 2,000-foot snow bank into Hat Creek on our way to Yellow Butte there was no sign of heat in the summit of Lassen Peak. The rocky summit of the peak, struck by many thunder-bolts during storms and superficially fused here and there by the lightning to fulgerite, is still as it was then, and the little lake is there as in 1883; but the heat and the crater are new. Mr. Rushing tells me that these new features appeared with the first eruption. But the fact that the other hot places about the mountain are not yet perceptibly hotter indicates that the rise of temperature is local and does not at least as yet affect the mountain mass. Time alone can tell what Lassen is going to do. The volcano may subside to its former quiescence. But we must not forget that it was only the top of the old Vesuvius that was blown off to make Monte Somma and the Vesuvius of to-day. Krakatoa blew up from the very base with tremendous effect. There seems no good reason at present to fear a Krakatoan outbreak at Lassen Peak, but the part of wisdom dictates a close watch."

On June 16th W. H. Wright, a mining engineer of San Francisco, visited this region and ascended the peak, and the following extracts from his personal observations, published in the *Engineering and Mining Journal*, give additional facts of interest.

"We visited the peak on June 10th, under guidance of Harry Kaul, who had spent the winter at Drake's Springs as caretaker. Kaul stated that on Thursday night, May 28th, he heard a rumbling like that of thunder. Upon going out of doors he found the stars shining brightly. Also that on Friday afternoon, at 2:30, a slight earthquake caused the poorly fastened roof of the barn to slide to the ground. This shock was felt in Westwood, twenty-nine miles, and Susanville, fifty-one miles, distant. At this time Kaul was probably the nearest to the mountain of any person in that region. On Saturday, May 30th, the first eruption occurred, although a stage driver reports seeing a vapor rising from the mountain on Friday. Two days after the eruption, Kaul accompanied a party to the peak. The crater or fissure was then about half its present size, but general conditions were the same. There was not so much *débris* scattered about, and a small pool occupied a depression in the old crater. Since that time numerous eruptions have taken place, and have all been of the same character.

"Leaving the Western Pacific Railroad at Keddie, we traveled by automobile to Big Meadows, a distance of twenty-six miles, to secure saddle horses. Then a horseback ride of thirty-five miles brought us to Drake's Springs, where the night was spent. This point is seven miles from the summit of the peak.

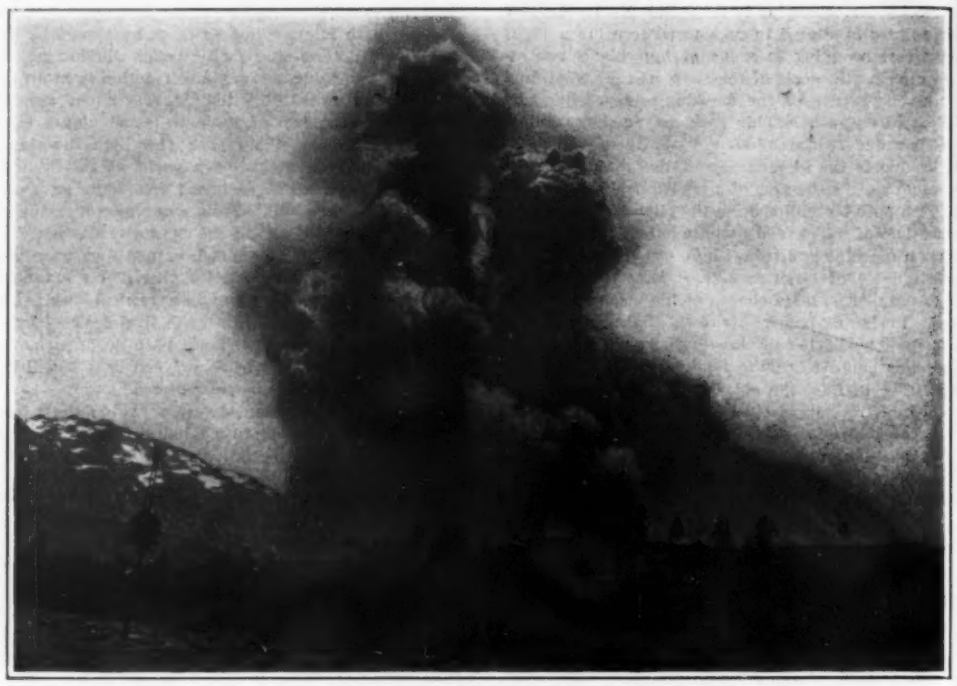
"About fifteen miles from the mountain, in a direct line, the first sign of volcanic dust was seen. A slight film covered the ground. This seemed to lie in a narrow belt, as we soon passed through it when our course was changed. At various times during the ride glimpses of the mountain were caught, and a column of steam was always seen rising high above the summit. At Lee's ranch, in Warner Valley, ten miles from the peak, we witnessed the second eruption of the day. This happened at 7 P. M. and was an impressive spectacle. The setting sun was level with the top of the peak and a little to the left. A column of steam and dust rose to a height of at least 1,500 feet above the mountain top. In appearance it much resembled the dirty white exhaust of a coal-burning locomotive. Although witnesses to this eruption, situated on the west and northwest sides of the mountain, reported that flames were visible, none could be seen from the southeast side. It is more than likely that the swift-rising column of steam reflected the red rays of the setting sun, giving an appearance of fire.

"The next morning, Monday, June 15th, the party visited Tartarus Lake. This is a pool occupying a crater-like depression, completely surrounded by boiling springs and mud pots. The steam from these has a decided odor of hydrogen sulphide. The area of this pool is approximately an acre. One large spring at the south end is almost a true geyser in its intense bubbling and spouting of steam. Two and one half miles southeast of this lake is Geyser, a large boiling spring, which formerly spouted to a considerable height, but is now quite feeble in its action.

"Two miles northwest of Tartarus Lake, and in the direction of Lassen Peak, is situated the Devil's Kitchen. This consists of a number of solfataras and hot springs that are on both sides of a ravine, through which runs a good-sized mountain stream. Some of the springs actually bubble up through the water of the creek. The action of these springs varies from the sluggish mud-pots to the violently boiling springs that are, in fact, small geysers. The springs after a time apparently become choked with a deposit from the water and form other vents in new places. In the same general line, but a trifle more to the west, Bumpass Springs are situated. This is a group of springs similar to those of the Devil's Kitchen, but on a much larger scale. Many other hot springs, as well as mineral springs, exist in other localities in this region. The steam from all of these springs has the same characteristic odor of hydrogen sulphide, and possibly of the dioxide, although this could not be definitely ascertained by the sense of smell alone.

"Tuesday morning, June 16th, guided by Harry Kaul, the party left Drake's Springs for the summit of Lassen Peak. Kaul had made two trips to the top of the peak since the first eruption of May 30th. The trail leads through a magnificent growth of timber. Above 6,000 feet altitude the traveling was done over hard snow, which as we neared the top became very deep. It easily supported the horses and made the ascent much easier than at other seasons. Even close to the peak only a slight amount of dust covered the snow.

"At 12:30 the ridge at the top was gained and our first view of the crater obtained. The party then descended the slope into the cup-shaped depression that marks the site of the ancient crater. The new crater has broken out on the northwest side of this, and seemingly has been formed by steam escaping under high pressure from a fissure which lies along the main axis of the oval-shaped pit. The steam forced its way through the fissure and formed a narrow crater, the sides of which had begun to cave, rapidly widening it. Pictures were taken at great risk. Aside from the danger of an outbreak of the crater, the danger from the caving sides was great. In order to get good views of the pit it was necessary to go close to the edge. Huge cracks extended back 25 to 30 feet. Every few minutes great masses would fall from the sides. A short time after one of the pictures was obtained, the place



Eruption at 10 A. M., June 14th. Picture taken one minute after explosion.

Eruption at 10 A. M., June 14th. Taken 30 seconds after previous view.

Photograph taken one minute after an explosion.

Manzaneta Lake and Lassen Peak.

View taken five minutes after an eruption.

from which it was taken suddenly fell into the hole, sending up a cloud of dust and making a spectacular display, which, unfortunately, was over too soon to be photographed, as the party was busily engaged in eating lunch. The volume of escaping steam varies from moment to moment. In appearance and odor the steam resembles that escaping from the boiling springs previously mentioned; in fact, it was impossible to detect any difference. That the vapor is steam is evidenced by the fact that it condenses and disappears after rising into the air for a short distance. The hole is about 100 feet in width and 500 feet in length, and large quantities of huge rocks were thrown out. The deep snow, on the north slope of the south side of the old crater, which was covered with dust, sand, and rocks, contained several hundred holes which had been caused by falling rocks. These must have been hot, as they were deep in the snow, which is as hard as ice; also, the sides of the holes are perfectly smooth, and there are many large stones lying on top of the snow beside these holes. Of course, it is possible that the unburied ones did not fall from as great a height as those that are buried.

"Small heaps of crumbled rock lying on the snow showed that some of the stones crumbled upon being suddenly cooled by it. At the edge of the crater, *débris* from the different explosions lay on the snow to a depth of three or four feet. This gradually diminished to a depth of 6 inches at the top of the ridge surrounding the cup of the crater. The deposit has been classified as descending from a great height. Upon the snow were stones of various sizes. Next is a deposit of coarse sand, upon which is a layer of very fine dust that closely resembles Portland cement. There was no lava or cinders. The only indications of heat were the hot stones and steam. The mountain is composed of dacite, which has the appearance of gray granite. If one could collect the *débris* from a blast in this rock, he would have exactly the same material that has been cast up by the present eruptions.

"The edges of the fissure are covered with a yellow deposit that appears to be sulphur. This could not be verified, as it was impossible to reach the fissure. An odor of sulphur was noticed in the dust, but it was so faint that it could not be determined whether it was the hydride or dioxide.

"The evidences on the ground bear out the belief that the material thrown out by the outbursts consisted of *débris* from the walls of the ancient crater broken and forced from the fissure by steam under great pressure. Much of this material fell directly back into the new crater or caved from the side, closing the vent and making other explosions necessary to clear the outlet. Lassen Peak is 10,437 feet high and is the southern terminus of the Cascade range. Like many other mountains in this range, it is an extinct crater. In the Lassen lava field, which lies to the northeast and north of Lassen Peak, is situated Cinder Cone, the latest active volcano in the United States. History does not record this last eruption, which appears to have occurred in the neighborhood of two hundred years ago. This eruption was so quiet that it would not attract attention in a sparsely settled country."

The Preservation of Wood—III*

A Synopsis of the Principal Processes in Use To-day

By A. J. Wallis-Tayler

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2013, Page 80, August 1, 1914

The Creo-resinate Process.—This process is used by the United States Wood Preserving Company of New York, and, according to good authority, is a very efficient one for wood paving-blocks. The chief novel feature in the process seems to be the substitution for steam of air raised to a temperature of 121 deg. Cent. (250 deg. Fahr.), and at a pressure of about 100 pounds to the square inch. The air pressure is claimed to prevent the checking of the block, and the air is kept at the same temperature and pressure until the center of the wood being treated reaches a temperature of 100 deg. Cent. (212 deg. Fahr.), at which all germ life, the chief cause of decay, is destroyed. The temperature of the air is then reduced to 65.5 deg. Cent. (150 deg. Fahr.), and subsequently the air is exhausted from the retort and a vacuum of 26 inches is pumped, the charge of antiseptic agent being then inserted. This agent consists of 50 per cent of oil of creosote, 48 per cent of resin, and 2 per cent of formaldehyde. This mixture is forced into the wood under pressure so that the pores are thoroughly impregnated, and 22 pounds per cubic foot are taken up. The wood is next transferred to another retort and treated with a solution of lime, raised to a temperature of 100 deg. Cent. (212 deg. Fahr.) and at a pressure of 150 pounds per square inch. The wood is then allowed to cool gradually.

The Guissani Process.—In this process the wood to be preserved is submerged in a bath of anthracene and pitch raised to about 140 deg. Cent. (284 deg. Fahr.), which temperature is below their boiling-point. Directly, however, the wood is placed in the bath, the mixture commences to boil, and steam and moisture being given off indicate the passing away of a portion of the constituents of the wood. The cessation of the ebullition—which occurs after from 2 to 4 hours—shows that all sap and moisture has been given off from the wood.

The wood is next transferred into a cold bath of heavy oil of tar, in which it is allowed to remain for about 10 minutes, and is afterward placed in a bath of cold chloride of zinc, in which it is kept until the desired amount has been absorbed.

This process also is claimed to be especially suitable for sleepers.

The Saccharine Solution, or "Powellizing" Process.—This process was first introduced by Mr. Powell, and is hence usually termed the "powellizing" process. The exact composition of the solution used is a secret, but it is stated to consist mainly of sugar with a small percentage of arsenic added, and probably several other ingredients.

The value of saccharine solutions for the preservation of wood is said to have been discovered from the fact that the timber of sugar vats is found to be to all intents and purposes everlasting. It is averred that sugar had never been employed for timber preservation before the idea occurred to Mr. Powell, which is probably true so far as treatment on a comparatively large scale is concerned.

The treatment is on the open-tank or immersion system, the treated timber being, however, subsequently subjected to artificial drying. Any description of tank may be used, but a convenient arrangement, especially designed for carrying out the process, comprises a tank of the requisite dimensions fitted with steam-heating pipes and having a water-tight door at one end through which loaded trucks can be run in on a set of tramlines. The tank having received its charge of timber, this door is closed and cold solution is admitted until the wood is covered. The temperature of the solution is then gradually raised to boiling-point, and kept at that temperature for several hours, the exact time varying in accordance with the dimensions and class of wood being treated. The solution is then permitted to cool down, after which it is run off and the timber is passed on into a drying-chamber in which the temperature is gradually raised until it has been sufficiently desiccated, when it is removed and is ready for use.

The air in the desiccating or drying-chamber is first raised to a temperature of from 55.5 deg. Cent. to 60 deg. Cent. (130 deg. Fahr. to 140 deg. Fahr.), with a humidity of 85-90 per cent, and subsequently this is slowly increased to a maximum of from 74 deg. Cent. to 76.5 deg. Cent. (165 deg. Fahr. to 170 deg. Fahr.), with a humidity of 35 per cent.

An advantage of considerable value possessed by this process is that green wood may be satisfactorily treated.

A microscopical examination of thin sections of wood treated as above, made by Prof. Norman Rudolf, M.Sc., F.I.C., revealed the fact that the cells were swollen up, some being apparently filled with saccharine matter in a non-crystalline form, the saccharine solution having actually become a part of the structure of the wood.

The Vulcanizing or "Haskinizing" Process.—The vulcanizing process, also known as the "haskinizing" process, from the name of its inventor, Col. Haskin, consists in roasting or subjecting the wood, which has been previously dried by steaming, to a temperature sufficiently high to coagulate the albumens contained in it, and in conjunction with pressure also to form new substances. In other words, the high temperature produces a resolution of the woody fiber and sap, and results in the production of wood creosote.

Albuminous food being essential to the life of both

* Paper read before the Royal Society of Arts and published in its *Journal*.

fungi and insects, an alteration in the condition of these albumens will render them unfit for the service of the destructive agents. The coagulation of albumens takes place between 71 deg. and 94 deg. Cent. (160 deg. and 201.2 deg. Fahr.).

An examination of wood treated by the vulcanizing process made by Mr. Chandler, of Columbia College, New York, showed 11.91 per cent of new substances had come into existence, viz., 0.36 per cent of neutral oils and turpines, and 10.78 per cent of resinous acids and other bodies, a large proportion of which consisted of antiseptic and preservative substances.

The plant required comprises one or more air-tight cylinders or retorts, wherein the timber to be treated can be subjected to heating and pressure, an air-compressor, and an air-circulating engine.

The details of the process are briefly as follows: The retort or retorts being charged with wood to be treated, steam is first injected to remove surface moisture from the timber, the moisture thus extracted being drawn off by means of cocks. Air is compressed in the compressor to a pressure of 200 pounds per square inch, the heat of compression being reduced by sparging or spraying with water, and the moist compressed air is dried and raised to a temperature of between 94 deg. Cent. and 204.5 deg. Cent. (201.2 deg. Fahr. and 400 deg. Fahr.), and is forced through the retort by the circulating engine, escaping past a loaded valve, the pressure being kept up by the compressor.

The time required for treatment is from 6 to 10 hours, in accordance with the dimensions of the timber.

This process is more effective in the case of green timber.

The Crésol-calcium Process.—This process, recently brought out by Messrs. F. Friedeman and G. von Heidenstam, consists in the use of an agent composed of a mixture of crésol and milk of lime, the proportions given being 15 grammes of burnt lime (90 per cent to 95 per cent), 46 cubic centimeters of crésol, containing at least 95 per cent of tar-acids, and 500 cubic centimeters of water.

The theory of the inventors is that 2 ounces of creosote per cubic foot is sufficient for purposes of impregnation, the larger quantities ordinarily employed being required owing to the difficulty of insuring even distribution. By mixing crésol with milk of lime they claim to bind the tar-acids by transforming them into salts soluble in water but not volatile. Ordinarily it is impracticable to use tar-acids for impregnation, or to use them in water solutions owing to their being too volatile. It is generally accepted that tar-acids are efficacious agents for timber preservation.

The plant required for carrying out the above process may be any of those ordinarily employed for impregnating timber by the pneumatic methods.

NATURAL OILS AS PRESERVATIVE AGENTS.

Recent experiments have demonstrated that natural oils can be used as preservative agents with a fair amount of success. It does not appear that such oils possess any antiseptic properties, but they serve the purpose of stopping up the open wood cells with a substance which becomes solid under ordinary temperatures, thus preventing heat, moisture, and air from penetrating into the wood, and obviating the assistance which they render to the decay-producing organisms in getting to work. This proposition seems reasonable enough, as it is generally held by timber experts that, in order to produce decay, moisture and heat must be present at the same time with access to the air.

The practice of the Atchison, Topeka and Santa Fé Railway is to use crude Californian oil of a very low specific gravity with about 75 per cent of asphaltum, and the remainder light oils, which vaporize on being heated. The oil is heated to 82 deg. Cent. (179.6. deg. Fahr.) and is forced into the wood at a pressure of from 150 pounds to 200 pounds per square inch. At normal temperatures the oil is of about the consistency of molasses, but when heated it becomes sufficiently fluid to allow of its penetration into the pores of the wood. A slight vacuum is applied at the close of the operation, which seals the pores and admits of the wood being handled without difficulty.

When the process is used for sleepers the amount of oil injected is from 4 to 8 gallons per sleeper, and excellent results are said to be attained as regards the prolongation of the life of the sleepers.

The above railway company, it is said, were induced to experiment with crude oil as a preservative agent owing to finding the life of untreated sleepers to be greatly prolonged on portions of its track on which the oil was sprinkled to keep down the dust. The coating of oil which spread over the tops of the sleepers kept off moisture.

ATLAS PRESERVATIVE SOLUTION.

The composition of this solution is a secret. It is poisonous, and causes irritation of a passing nature on contact with the skin. The treatment of timber with this agent consists in the immersion in a bath of the cold solution of a strength of from 15 to 25 per cent for a period of time dependent upon the size and nature of the wood to be treated. In the case of sleepers from 24 to 36 hours will be required.

After the treated timber is dry, it should, according to the makers, be given a coat of hot gas-tar, probably to prevent leaching.

ANTHROL.

This is a proprietary antiseptic solution, made by the Anthrol Company, which can be used as a paint, or for the immersion or open-tank process. The solution is preferably employed in a heated condition.

BÉLLIT.

This is also a proprietary solution possessing antiseptic or preservative qualities, and consisting of a 2 per cent solution of dinitro-benzol and mineral oil. It has a boiling-point of 300 deg. Cent. (572 deg. Fahr.). The mode of application is the same as with "Anthrol."

BURNETTIZINE.

Is a preservative solution made by Sir W. Burnett & Co., Ltd. It is used by the Post Office for telegraph poles where creosoting would be undesirable, also by railway, dock, and shipping companies.

This agent is claimed not only to preserve the wood against decay, but to render it practically fireproof as well as strengthening it, and, moreover, to leave it clean and odorless. It is said to enter the heart of the wood and form an insoluble chemical combination that will not wash out.

CARBOLINEUM.

Oils obtained from the distillation of coal-tar consisting of such oils heavier than water, as, with tar-acids, help to form creosote. There are two well-known grades of this oil on the market, carbolineum Avenarius, a preservative solution, introduced over 30 years ago by Mr. Avenarius, and carbolineum "marque de lion."

An analysis made by Dr. Filsinger of the first mentioned (see "Preservation des Bois," Henry) shows it to contain oils distilling at 230 deg. Cent. (446 deg. Fahr.), and to possess a density of 1.128, viscosity at 17 deg. Cent. (62.6 deg. Fahr.), as compared with water 10, to contain 10.6 per cent per volume of oils distilling between 230 deg. Cent. (446 deg. Fahr.), and 270 deg. Cent. (518 deg. Fahr.), and 12.2 per cent of oils coming over between 270 deg. Cent. (518 deg. Fahr.) and 300 deg. Cent. (572 deg. Fahr.). The residue is a thick, limpid red-brown mass.

Carbolineum heated to from 65 deg. Cent. to 94 deg. Cent. (149 deg. Fahr. to 201.2 deg. Fahr.) can be either applied to the wood with a wire brush, or the timber to be treated can be immersed in a bath of the warm solution according to the open-tank method, the best temperature for the bath being 95 deg. Cent. (203 deg. Fahr.), and the timber being allowed to remain in soak 5 to 15 minutes, according to dimensions and character.

Experiments have demonstrated that, in the case of hard woods such as oak and beech, the amounts absorbed by the woods in a bath of carbolineum at a temperature of 60 deg. Cent. (140 deg. Fahr.) were not increased to any appreciable extent by prolonging the immersion to 20 minutes. It also appears that an increase in the temperature of the bath to 80 deg. Cent. (176 deg. Fahr.) and over has no effect upon the amount of the oil absorbed by the wood.

GREEN OIL.

This is a product of creosote, and is used in a similar manner to carbolineum.

HYLINIT.

This preparation is a proprietary article, the composition of which is a secret.

The strength of the solution for treatment by immersion is given by the makers as 5 per cent, and the wood should remain in the bath for 24 hours.

JODELITE.

Another proprietary antiseptic, used in a similar manner to carbolineum.

The treatment by open-tank method takes from 10 to 40 minutes, in accordance with the density of the wood. The solution should be heated to from 82 deg. Cent. to 94 deg. Cent. (179.6 deg. Fahr. to 201.2 deg. Fahr.).

MICROSOL.

According to an analysis made by Prof. Arth ("Preservation des Bois," Henry), this solution consists of sulphate of copper, 70 per cent, in crystalline and powdered form, sulphate of soda, sulphate of lime, small trace of free silicate, and a copper salt of sulpho-phenol.

The treatment is the same as with carbolineum, the strength of the solution varying from 2 per cent to 4 per cent, and the time required being 24 hours or more immersion, according to the nature, etc., of the wood.

This preparation is well spoken of on the Continent.

SOLIGNUM.

A proprietary antiseptic solution made by Major & Co., and applied with a brush, either cold, or, when climate conditions render it advisable, heated to from 71 deg. Cent. to 82 deg. Cent. (160 deg. Fahr. to 180 deg. Fahr.). This solution has a tendency to work downward.

OTHER PROCESSES AND SOLUTIONS.

Among the numerous other processes and patent or proprietary and other preservative solutions, many of which have been used with considerable success, mention may be made of the following: Beaumartin's process for impregnating wood with various metallic salts, on the principle of osmosis produced electrically. According to *L'Electricien*, Paris, 1906, the timber is first placed in a retort, and copper or zinc sulphate, or sodium silicate, is injected under pressure. The wood is then subjected to the action of an alternating current of electricity, by means of which the state of the fibers and the sap, and of the injected salts, is so modified that the last combine with the organic elements of the sap and incrusting matter and form insoluble salts which remain fixed on the fibers and prevent putrefaction. The alternating currents, moreover, it is claimed, destroy all vegetable and animal germs, and cause the fibers themselves to be so transformed as to increase both their tenacity and their mechanical resistance. Zinc-chloride and sodium-fluoride mixed in equal quantities are recommended by Mr. H. B. Malenkovic; the strength of the solution, which is used according to the open-tank system, is 3.5 per cent ZnCl and 3.5 per cent NaF. For mine timber the United States Forest Service have experimented with (1) a preservative agent consisting of creosote and carbolineum Avenarius heated to a temperature of 82 deg. Cent. (180 deg. Fahr.) and applied in two coats with a brush; (2) a bath composed of a 15 per cent solution of common salt and a 6 per cent solution of zinc-chloride and creosote, the wood being immersed or steeped in an open tank in successive hot and cold baths of this agent; (3) treatment in a closed retort in a vacuum and under pressure, the agent used being zinc-chloride solution and creosote. In a modification of Blythe's system the wood is submitted in a retort to the action of superheated steam at a minimum temperature of 200 deg. Cent. (392 deg. Fahr.), which steam is caused to pass over a reservoir containing creosote, the products of condensation, comprising water and creosote, being then drawn off, the retort filled with a charge of creosote, and steam pressure applied, the creosote being extracted from the water evacuated during the first stage for further use.

A system used in France many years ago, and said to have given excellent results, consists in placing the wood in a tank with a layer of quicklime on the top, which lime is slowly slaked with water, the time required for this treatment being about seven days. The timber so treated is said to acquire a remarkable degree of hardness. A process used in Belgium consists first in exposing the wood in a retort to a vacuum and afterwards impregnating under pressure with an agent formed by a ⅔-solution of gutta-percha to ⅓ of paraffin and heated until sufficiently liquid. An infusion of quassia wood has been used with some success. A strong solution of sulphate of iron and sulphate of copper, injected under pressure (Boucherie and Sage and Fleury-Pironnett processes). A steaming-vacuum-pressure process, sulphate of copper (Sage and Fleury-Pironnett), this process should be carried out within about ten days of felling the timber, and the life of wood so preserved is affected by the nature of the soil it may come in contact with. Tungstate of soda and water solution of a specific gravity of 1.2 (Jones's process). Sulphur immersed in nitric acid and distilled (Evelyn's process). Hot anthracene oil used at Dortmund collieries. To every gallon of water 3 ounces croton tiglium seeds, 3 ounces margosa bark, 3 ounces sulphur, 2 ounces blue vitriol, solution for preventing attack by white ants. "Sotor," preparation for protecting wood exposed to the action of sea water from attacks of the toredo navalis, and preventing decay (Peters). "Stoprot," a preventative of decay and dry rot, claimed also to be proof against insects and suitable for use in tropical climates, solution applied hot (Plichers). "Sideroleum" consists of a blend of hydrocarbon oils, claimed to possess great penetrative powers, and to carry the carbon into the pores of the wood without pressure, rendering sappy wood hard and rot proof. Applied cold by brush, and imparts a brown finish to wood (Anderson). Pfister's method of diffusion in freshly-hewn wood. Impregnation with molten sulphur. Faleir's method of destroying the fungi or dry rot in buildings effected by heating beyond 40 deg. Cent. (104 deg. Fahr.), which is the temperature at which the mycelium of the merulius is killed. Owing to the fact that wood is a poor conductor of heat, it is considered desirable to raise the temperature of the entire building to 42 deg. Cent. (107 deg. Fahr.), and to maintain this temperature for at least 2 hours. It is important to be quite certain as to the exact nature of the growth, as if the fungi be grown inside the wood heat will only expedite the work of destruction, as fungi of this class flourish more actively at the temperature fatal to the dry-rot fungus. A combined seasoning and preservative process used in France consists of a tank charged with

ABSORPTION LIMIT OF HARDWOODS.
(From various authorities.)

		Pounds per cubic foot.
Blue Gum (Eucalyptus Globulus)	Australia	¾
Ironwood (Bumelia lycioides)	Eastern United States	1
Jaman	India	¾
Locust (Robina pseudacacia)	United States	¾
Mahogany (Suretema mahogoni)	Central America, Cuba	¾
Oak (Quercus robur, etc.)	Europe, etc	4–5
Teak (Oldfieldia Africana)	West Africa	1¾
Teak (Tectona grandis)	India	1¾
Sâl or Saul (Shorea robusta)	India	1
Sisso (Dalbergia Sisso)	India	3¾
Sundri	India	2¼
Swan River Wood	Australia	1¾

a solution composed of 5 per cent resin, 10 per cent borax, a trace of carbonate of soda. The wood is stacked on a lead plate in the bottom of the tank, and another lead plate is placed on the top, the former being connected with the positive pole, and the latter with the negative pole, of a dynamo. The current passes from the upper plate through the wood, by which it is said the sap of the wood is driven out, and the resin and borax takes its place, filling up the cells and interstices.

AMOUNT OF PRESERVATIVE ABSORBED BY VARIOUS WOODS.

In India the amount of absorption by hard woods, such as terminalia, tomentosa, and mesua ferrea, is stated to be 3 pounds per cubic foot; moderately hard woods, such as diptero-carpus tuberculatus, etc., 6 pounds per cubic foot; and soft woods such as pinus excelsa, pinus longifolia, etc., 10 pounds per cubic foot.

In France the woods most commonly used for sleepers are oak, beech, or pine, but fir, larch, and chestnut are occasionally employed. The French practice is to impregnate oak sleepers of about 3 cubic feet with from 8.8 to 12.3 pints of creosote; beech or pine sleepers, with about 44 pints of creosote each, the question of expense, however, frequently rendering it desirable to do with a less amount. According to the writer of an article which appeared in 1895 in the *Revue Générale des Chemins de Fer*, the weights of creosote injected per sleeper by the principal French lines for different kinds of wood, are as follows:

Description of Wood.	Railway.	Pounds.
Oak	All	11 to 15.5 (absorp. limit)
Beech	Northern	28.5
Beech	Western	33 to 35.25
Beech	Paris-Lyons-Mediterranean	35.25
Beech	Eastern	53
Pine	Midi	26.5 (absorption limit)
Pine	Orleans	31 "
Pine	Paris-Lyons-Mediterranean	26.5 "

Present practice tends to the injection of an increased amount of oil per sleeper. A report, presented at the International Railway Congress in 1895 by Mr. Herzenstein, states that the practice on the various lines in this country was to inject from 7 to 10 pounds of oil per cubic foot, with an average life of 16 to 20 years, an injection of from 7 to 8 pounds per cubic foot giving an average life of from 12 to 15 years. The amount inserted, according to later practice, is from 30 pounds to 35 pounds per sleeper. In France 48.4 pounds of oil per sleeper is used as a minimum.

On Indian railways the amounts of oil injected into sleepers of various woods are as follows: Beech and pine, 10 pounds of creosote oil per cubic foot; harder woods, such as oak, 3 pounds per cubic foot; piles of coniferous woods, 20 pounds per cubic foot. When chloride of mercury is used as an antiseptic, the amounts used per cubic foot are for hard wood, 3 pounds, moderately hard, 6 pounds, and soft, 10 pounds.

Mr. J. R. Baterden states (*Proceedings* Inst. C. E., 1904) that he has experienced no difficulty in getting into pitch-pine 7 pounds of creosote oil per cubic foot.

In the United States the usual amounts of creosote oil specified to be injected are as follows: For railway ties or sleepers, from 10 to 12 pounds per cubic foot; for dimension timbers, from 15 to 20 pounds per cubic foot; for piles, from 20 pounds to 30 pounds or more per cubic foot. Other experts advise the injection into the wood, in the full cell creosote process, of from 6 pounds to 12 pounds of creosote oil per cubic foot in the case of railway ties or sleepers, and from 10 pounds to 20 pounds per cubic foot in the case of timber and piling.

In the Rueping and Lowry processes the wood is first impregnated with from 10 pounds to 12 pounds of creosote oil per cubic foot, the amount left in the wood fibers on leaving the retort being from 2 pounds to 6 pounds per cubic foot.

Mr. J. B. Card, writing to the *Engineering News* (New York) in October, 1908, remarks that the treatment of sleepers with small doses of creosote oil has not been a success either in the United States or in Europe.

In Germany the usual amount of oil used for the impregnation of sleepers is 12 pounds per cubic foot.

Messrs. Richard Wade, Sons & Co., Ltd., who use the Rueping process on an extensive scale for treating telegraph poles, give the following results of a test with the latter as to amount of creosote oil absorbed and subsequent loss through draining out or leaching:

No.	L.	Diameter, middle.	Cubical contents. Caliper measure.	Weight before creosoting. October 13th, 1910.	Weight after creosoting. October 13th, 1910.	Absorption of creosote per cubic foot.	Subsequent Weighings. Nov. 1st, 1910.	Jan. 21st, 1911.	May 11th, 1911.	July 10th, 1911.	Loss of creosote per cubic foot.
		ins.		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	24	6½	5.53	258	318	10.85	312	290	280	278	7.23
2	24	7¼	6.88	292	402	15.98	397	379	356	241	8.87
3	24	7¼	6.88	248	344	13.98	340	318	302	293	7.41
4	24	7¼	6.88	268	398	18.89	393	371	360	334	9.30

LIFE OF PRESERVED WOOD.

Mr. V. Herzenstein, in the *Bulletin* of the International Railway Congress (July, 1910), from information collected from a number of railway companies, gives the average life of creosoted sleepers to be as follows:

Description of Sleeper.	Main Line. Years.	Sidings. Years.	Total Years.
Creosoted Pine	15	5	20
Creosoted Oak	18	7	25
Creosoted Beech	20	10	30

Mr. Hausser, of the Midi Railway Company, France, in his report to the Seventh Session of the Railway Congress, says: "Although it is very difficult to lay down a rule that would be at all generally applicable, it may, however, be said that there is a unanimous opinion that pickling or preserving materially lengthens the life of sleepers, approximately doubling it in the case of oak, tripling it in the case of pine, and quintupling it in the case of beech."

A record of the removals of ties or sleepers on the New Mexico and Colorado divisions of the Atchison, Topeka and Santa Fé Railway, carefully kept from 1897 to 1907, shows the average life of these sleepers, which were treated on the zinc-tannin or Wellhouse process, to be 13.11 years. The number of ties or sleepers treated in 1885 was 111,503. At the end of 1907 the records showed that 77,000 had been removed 21 years after laying down, thus leaving 34,503 as having been removed during the years when no record was kept. It is to be observed that no care was taken in selecting the above 111,503 sleepers, and that many thousands of them are said to have progressed so far toward decay that but little prolongation of life could be secured from the preservative treatment. Had all the sleepers been carefully selected the average life would undoubtedly have been found to be considerably longer. The records of the Southern Pacific Railway show a mean life of from 8 to 9 years for burnettized ties or sleepers.

The *Engineering News* (New York) states that results obtained in the United States show that, by the zinc-chloride or burnettizing treatment, the life of the soft woods is more than doubled, meaning a life of from 8 to 12 for pine that usually lasts from 2 to 5 years. This is the mean life, the actual life being from 5 to over 20 years for treated pine ties or sleepers, against from 2 to 7 for the untreated ones. Creosoting gives from 25 to 50 per cent more life than the zinc-chloride process, but the cost of the former is three or four times that of the latter, and moreover, in the case of several woods creosote oil can only be made to effect a superficial penetration. The injection of from 10 to 15 pounds of creosote oil per cubic foot of wood, according to Mr. Card, gives a life of from 12 to 20 years.

LIFE OF UNTREATED AND TREATED SLEEPERS FROM DATA GIVEN AT THE LEWIS AND CLARK EXHIBITION, PORTLAND, ORE., 1905.

Species of Sleeper.	Process.	Life Untreated.	Life Treated.
		Years.	Years.
Texas Long-Leaf Pine	Rueping	4 to 6	15 to 20
Texas Short-Leaf Pine	Rueping	3 to 5	10 to 15
Texas Loblolly Pine	Rueping	2 to 5	10 to 15
Washington Red Fir	ZnCl.	5 to 6	10 to 12
Mont. Lodgepole Pine	ZnCl.	4 to 5	10 to 12
Black Hills West-Yellow	ZnCl.	5 to 6	10 to 12
Michigan Hemlock	Wellhouse	5	10
Michigan Tamerack	Wellhouse	5	10 to 15
Beech	Creosote	4 to 5	20 to 30
Red Oak	Creosote	4 to 5	20 to 30

Mr. Batterden (*Proceedings* Inst. C. E., 1904) states that about 7 pounds of creosote oil per cubic foot injected into piles at a temperature of 49 deg. Cent. (120 deg. Fahr.), and pressure of 150 pounds per square inch, gave protection against the marine worm for 18 years.

Mr. De Kermond (*L'Electricien*, Paris) states that official tests have shown that posts treated with copper sulphate have a life of 13 years 9 months; by the Kyan or mercuric-chloride process, nearly 17 years; and by the creosoting process, 19 years 8 months.

COST OF PRESERVATIVE TREATMENT.

The cost of pickling or treating wood varies considerably, according to the wood being treated, the process employed, and the country, or even the district, where the work is being carried out, etc.

The cost of creosoting in England on the pressure system varies from 3d. to 5d. per cubic foot, in accordance with the price of the oil and the amount injected. For estate work the amount of oil used for impregnation is generally about 0.75 gallon per cubic foot, and the labor of attending to the working of such a creosoting plant is calculated at 0.5d. per cubic foot. At the present time the price of creosote oil is 4d. per gallon, so that the price works out at 3.5d. per cubic foot. Creosoting timber for railway purposes costs for pine and fir from 2.9d. to 5.1d. per cubic foot.

In India the cost of impregnating railway sleepers is given as 1s. for 3 pounds, 2s. for 6 pounds, and 3s. for 10 pounds, impregnation per cubic foot, with creosote oil at 7 annas (10½d.) per gallon.

In France creosoting on the Paris-Lyons-Mediterranean Railway is given by Mr. Herzenstein (*Bulletin* of the International Railway Congress, 1901) as for oak 1.6d. per cubic foot, for fir 5.4d. per cubic foot. On the Northern Railway, with the Blythe creosoting process, 1.8d. per cubic foot for oak, and 3.5d. per cubic foot for fir. A writer in the *Revue Générale des Chemins de Fer* gives the average cost of creosoting on French railways as being, for oak 8.6d., and for beech or pine from 1s. 3.5d. to 1s. 9.3d. per sleeper, according to the amount of oil injected.

		Per Sleeper.
1	Burnettizing or zinc-chloride process (about ½ pound of dry zinc per cubic foot)	$0.12 (6d.)
2	Wellhouse or zinc-tannin process (½ pound of dry zinc plus glue and tannin per cubic foot)	.16 (8d.)
3	Card, Rutger or zinc-creosote process (1½ pounds of creosote oil and 1 pound of dry zinc per cubic foot)	.18 (9d.)
4	Rueping, partial cell process (about 6 pounds of creosote oil per cubic foot)	.225 (11d.)
5	Lowry, partial cell process (6 pounds of creosote oil per cubic foot)	.225 (11d.)
6	Absorption or open-tank process (about 6 pounds of creosote oil per cubic foot)	.230 (11.5d.)
7	Full cell creosote process (about 10 pounds of creosote oil per cubic foot)	.335 (16.5d.)

In the United States, from information compiled by Mr. J. D. Isaacs, Permanent Way Engineer to the Southern Pacific Railway, it appears that at Oakland, Cal., and Latham, Ore., the amount of creosote oil injected is from 1.12 gallons to 1.18 gallons per cubic foot, or an average of about 10 pounds per cubic foot, and the average cost (including price of oil, fuel, labor, maintenance, oil waste, and water) is 15.96 cents, or about 8d. per cubic foot. The average tie or sleeper used in the United States contains approximately 3.5 feet.

The cost of treating best woods for paving-blocks with 16 pounds of oil per cubic foot is 16 cents (8d.) per cubic foot. On the authority of Mr. Rowe, for the full creosote process, with an injection of 15 pounds of oil per cubic foot, a 3 cubic foot tie or sleeper would cost 38.36 cents (19.18d.), and a 3.75 cubic foot tie or sleeper 47.95 cents (23.97d.). This works out at 12.78 cents (6.39d.) per cubic foot, and 12.52 cents (6.26d.) per cubic foot.

The Allis-Chalmers Company, Milwaukee, Wis., give the following as the approximate cost of treating sleepers, exclusive of royalties, by the seven most-used preservative processes, the average size of hewn tie or sleeper being 7 inches × 9 inches × 8 feet = 3.45 cubic feet:

COST OF TREATING SLEEPERS FROM DATA GIVEN AT THE LEWIS AND CLARK EXHIBITION, PORTLAND, ORE., 1905.

Species of Tie.	Process.	Amount of Preservative.	Cost of Treatment.
Texas Long-Leaf Pine	Rueping	16 pounds creosote per sleeper	16 cents. (8d.)
Texas Short-Leaf Pine	Rueping	16 pounds creosote per sleeper	16 cents. (8d.)
Texas Lob'olly Pine	Rueping	16 pounds creosote per sleeper	16 cents. (8d.)
Washington Red Fir	ZnCl	½ pound creosote per cubic foot	10 cents. (5d.)
Mont. Lodgepole Pine	ZnCl	½ pound creosote per cubic foot	10 cents. (5d.)
Black Hills West Yellow	ZnCl	½ pound creosote per cubic foot	10 cents. (5d.)
Michigan Hemlock	Wellhouse	½ pound creosote per cubic foot	12 cents. (6d.)
Michigan Tamerack	Wellhouse	½ pound creosote per cubic foot	12 cents. (6d.)
Beech	Creosoted	56 pounds creosote per sleeper	60 cents. (2s. 6d.)
Red Oak	Creosoted	25 pounds creosote per sleeper	30 cents. (1s. 3d.)

Approximate cost of treating wood paving-blocks, the usual dimensions being 3.5 inches to 4 inches deep and cut from timber 3 inches × 6 inches, 3 inches × 8 inches, 3 inches × 10 inches, 4 inches × 6 inches, or 4 inches × 10 inches. Seasoned blocks, weighing about 20 pounds per cubic foot. Cost based on creosote oil at about $0.07 per gallon, and balance of treatment $0.02 per cubic foot.

The cost of treating piles is said to be $0.10 per cubic foot, with 10 pounds of oil per cubic foot, each additional pound of oil costing an additional cent. Piles range from 8 inches to 20 inches in diameter, and from 10 feet to 90 feet in length, the average sizes running about as follows: 10 inches to 14 inches diameter, by 28 feet in length; 11 inches to 15 inches diameter, by 40 feet in length; 8 inches to 18 inches diameter, by 60 feet in length; 8 inches to 20 inches diameter, by 90 feet in length. Green piles weigh about 55 pounds per cubic foot, and seasoned or steamed piles, about 40 pounds per cubic foot. The average treatment of piles in the United States is from 10 pounds to 20 pounds of creosote oil per cubic foot.

The cost of creosoting timber with 10 pounds of creosote oil per cubic foot is about $8 per thousand board feet, and for each additional pound of creosote oil used $0.75 must be added, creosote oil being taken at $0.07 per gallon.

The cost of the chloride of zinc or burnettizing process for timber, with ½ pound of dry zinc chloride per cubic foot, is about $3 per 1,000 board feet. Treatment with "burnettizine" costs about the same as creosoting, viz., 5d. per cubic foot.

The price of corrosive sublimate used in the kyanizing process has, combined with the slowness of the process, caused it to fall into disuse in England, and, at the present time, probably the United States is about the only place where it is still used to some extent in certain localities where there is a difficulty in obtaining chloride of zinc and oil of creosote. In England the price of corrosive sublimate is such as to render its use as a preservative agent impossible, with creosote oil in the neighborhood of 4d. per gallon, and pure zinc-chloride at 2d. per pound.

The cost of treating sleepers on the chloride of zinc process has been found by the Southern Pacific Railway Company to average, with two of its portable plants, 8.20 cents (4.1d.) and 7.41 cents (3.7d.) per tie or sleeper, or 2.5 cents (1.25d.) per cubic foot.

The zinc-tannin, or Wellhouse process, is considerably more expensive, the actual cost at four of the standard works in the United States is given by Mr. Rowe as being, for a 3 cubic feet sleeper, 7.81 cents (3.9d.) for chemicals, and 4.61 cents (2.3d.) for labor, or a total of 12.42 cents (6.21d.) per sleeper. According to this the cost per cubic foot is slightly over 4 cents (2d.).

The Rueping partial cell process, with an impregnation of 5 pounds of creosote oil per cubic foot, and taking the oil at 4d. per gallon, costs about 2.75d. per cubic foot.

The cost of the zinc-creosote process (Rutger and Card) would be about 3.25d. per cubic foot, the higher cost being due to the zinc-chloride required per cubic foot in addition to the creosote oil.

The cost of preserving by the Crésol-calcium process is stated to be as follows: In England, 0.47d.; in Sweden, 0.5d.; and in India, 0.6d. per cubic foot.

The cost of the saccharine or powellizing process is given as being in Bombay 5 annas (7.5d.) per cubic foot, and in Western Australia 3.68d. per cubic foot, plus the royalty to the patentees. Where sugar is very cheap, the cost, exclusive of royalties, would, according to Mr. Ryan, be 1.36d. per cubic foot.

The following is the approximate average cost of impregnation with 15 different antiseptics, including processing, from various sources:

	Process.	Cost per cubic foot
1	Atlas (10 per cent solution)	3d.
2	Bélit	1.75d.
3	Carbolineum	1.5 to 3.8d.
4	Chloride of zinc	.72 to .94d.
5	Chloride of mercury	8d.
6	Crésol-calcium	.46 to .6d.
7	Crésoyle	3d.
8	Green oil	1.9 to 4d.
9	Jodelite	4.9 to 7d.
10	Microsol	3 to 4d.
11	Rueping	1.2d.
12	Saccharine solution	1.36 to 7.5d.
13	Solignum	4.2d.
14	Sulphate of copper	5.2d.
15	Vulcanizing	2.5 to 4d.

CONCLUSION.

Fundamental Points to be Considered in Plans of Wood-preserving Works.—The following points are given by Mr. Rowe as the result of extensive experience in the United States: (1) That the works should be proportioned throughout to secure the desired output. (2) That each part should be proportioned to do the desired work, and at the same time so proportional to all the other parts that there will be no useless or surplus capacity or useless cost. (3) That each part perform its functions in the most direct and in the simplest manner. (4) That every part be of the best manufacture, and the most reliable for lasting service, so that repairs will be infrequent, saving loss of time and expensive maintenance. (5) That the working parts be so arranged as to be promptly operated with the least manual labor. (6) That the plans of all the essential parts be fully designed and prepared so that there will be no extra labor or delay during erection. (7) That the arrangement of the works be such that accurate measurements and weights shall be provided for, so that it shall be possible to know what is being done at any one time. (8) That the operator at the works shall be thoroughly competent, experienced, thoroughly honest and faithful, so as to be a safeguard between the two parties concerned.

The approximate weights in tons of machinery, etc., with two retorts for working the five most-used processes are as follows: Zinc-chloride or burnettizing, 226; zinc-tannin or Wellhouse, 331; zinc-creosote or Rutger, 331; Rueping, 351; creosoting, 316.

The following practice has grown up at Mr. Octave Chanute's works: (1) To refuse to treat freshly cut timber, but to put all such timber down to season. (2) To begin the spring season's treating by steaming no matter less the timber is of the previous year's cutting. (3) To omit steaming in summer and autumn when the timber proves to be well seasoned.

Depth of Block		3½ inches	4 inches
Pounds of creosote per cubic foot	To each square yard of blocks	2.63 cubic feet 42.08 pounds	3.00 cubic feet 48.00 pounds
16	Creosote	42.08 pounds	48.00 pounds
	Weight after treatment	147.28 pounds	168.00 pounds
	Approximate cost of treating	$ 0.39	$ 0.45
18	Creosote	47.34 pounds	54 pounds
	Weight after treatment	152.43 pounds	194.00 pounds
	Approximate cost of treating	$ 0.44	$ 0.50
20	Creosote	52.60 pounds	60.00 pounds
	Weight after treatment	157.80 pounds	200.00 pounds
	Approximate cost of treating	$ 0.48	$ 0.54

Vesuvius as a Fertilizer.—A Swiss scientist, Dr. Kleiber, has discovered that the ashes which still largely cover Herculaneum and Pompeii contain large quantities of potash and clay, from which an excellent agricultural fertilizer can be obtained. The whole region is very rich in potash, and it is said the Italian government is seriously intending to organize the exploitation of "Vesuvian Mines."—*Les Annales.*

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